A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES

– CASE STUDY OF AL-MAROOJ COURTS AT KFUPM

BY

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Dedicated to my *late father* Alhaji Mas'ood Oladapo Sanni-Anibire

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ABSTRACT

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Thesis Title : A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF AL-MAROOJ COURTS AT KFUPM

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Re-occurring failure of housing projects is due to the lack of feed-back and lessons-learnt derived from the end-users' or occupants' perspective. This can be achieved through Post Occupancy Evaluation studies; however most of the POE-studies that have been carried out fall short in the procedures and techniques employed. Thus it is the purpose of this research to develop a more qualitative and comprehensive approach to POE. It presents a holistic post occupancy evaluation framework and its application to a campus residential facility as a case study. This consisted of two parts. The first part is the development of a holistic questionnaire tool based on an extensive review of relevant literature, interviews with industry experts and review of documents to identify as many key performance indicators as possible. The second part was an application of the questionnaire tool together with other evaluation techniques such as: interviews; walkthroughs; and spot measurements. The implication of this study is to fill the need for more holistic forms of POE in the property sector; this will help to derive more qualitative feed-back from building occupants and thus a robust and more realistic decision making process for facility managers, housing administrators, designers, engineers and other stakeholders of the building and construction industry.

ملخص الرسالة

الاسم الكامل: معز اولادابو ساني انيبيري

عنوان الرسالة: إطار كلي لتقييم ما بعد الإشغال لاسكان جامعية - دراسة حالة المروج في جامعة الملك فهد

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يرجع سبب تكرار الفشل في مشاريع الإسكان إلى عدم وجود تغذية راجعة او دروس وعبر مستمدة من وجهة نظر المستخدمين. ويمكن تحقيق ذلك من خلال دراسات التقييم لما بعد التشغيل .(POE) ان كثيرا من دراسات POE والتي نفذت فيها تقصير من ناحية الإجراءات والتقنيات المستخدمة، وبالتالي فإن الغرض من هذا البحث يأتي لوضع نهج ذي نوعية أفضل وأكثر شمولا لهذه الدراسات . POE ويتمثل هذا الغرض في وضع إطار كلي لتقييم ما بعد التشغيل (POE) وتطبيقه على منشأة سكنية في الجامعة كحالة دراسية، وهذا يتألف من جزئين، الجزء الأول وهو تطوير استبيان شامل بعد الاستناد إلى الكثير من المؤلفات العلمية ذات الصلة، وعمل مقابلات مع الخبراء في هذا المجال، واستعراض الوثائق لتحديد العديد من مؤشرات الأداء الرئيسية قدر الامكان. وكان الجزء الثاني لتطبيق أداة الاستبيان جنبا إلى جنب مع تقنيات التقييم الأخرى مثل: المقابلات، والجولات والقياسات الميدانية. تأتي الآثار المترتبة على هذه الدراسة لملئ الحاجة إلى دراسات POE أكثر شمولية في قطاع العقارات، هذا وسوف تساعد على تحسين نوعية التغذية الراجعة الصادرة من شاغلي المبنى، وبناء عليه تصبح عملية صنع القرار اكثر قوة واقعية لكل من مديري المرافق والعقارات، المصممين، ،المهندسين، وغيرهم من أصحاب المصلحة في صناعة البناء والتشييد.

CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 Domestic Housing Facilities

In Maslow's hierarchy of needs food and shelter are amongst the most essential needs for the survival and function of the human body. Shelter is a basic architectural structure to protect against harsh climatic conditions. This definition however is a primitive perception of shelter when compared to a "civilized" domestic housing. A domestic housing facility apart from protecting against harsh exterior environmental conditions, provides comfort and accommodation for more demanding domestic activities. It is a combination of economic, sociological and physiological characteristics to form a unique home representing status, achievement and social acceptance. According to the World Health Organisation (WHO), the quality and size of housing is important for privacy, security and an enjoyable domestic life. While the quality of the neighborhood in which it is located is important in terms of the access it provides its residents to social amenities and city services. Thus without doubt, a comfortable housing is very important in fulfilling human needs and expectations (Fatoye & Odusami, 2009).

Mass housing delivery is practiced internationally and it depends on the rise and fall of the real estate market. In Saudi Arabia, the development of huge medium-rise housing projects boomed in the 1970s-1980s followed by a decline in the following years. The rise in the Saudi Arabian economy in the early 1990s ushered in a new phase of development as a result of a number of factors including a significant rise in population. The two-storey residential duplex is a typical type of housing in Saudi Arabia (Alsaati, 2006).

1.1.2 Campus Housing Facilities

The history of Campus Housing Facilities dates back to the establishment of the oldest university in the world in 969AD - the Al-Azhar University in Cairo, Egypt. Campus Housing Facilities became a fully fledged establishment in the 14th century with the provision of new college dormitories for a complete accommodation of teaching and living requirements by Oxford University, United Kingdom (Hassanain, 2008).

Campus Housing Facilities were later adopted in the United States to be an integral part of almost all American University campuses; expanding from Harvard University's initial gathering of student and faculty houses and classrooms to the elevated concept of Thomas Jefferson's academical village. The end of the World War II ushered in a number of developments in the housing industry. In the United States of America, the "1963 higher education facilities act" supported a diversity of residents and housing type, from classic single undergraduates to couples housing for both graduates and undergraduates to junior and senior faculty condominiums (Neuman, 2013).

Campus Housing is a continuously evolving subject for planning, programming, and design; since its quality is a critical and integral part of the overall educational experience (Neuman, 2013). It establishes a sense of belonging, essential to retain highly motivated environment and good quality staff (Hassanain et al., 2010). Thus to meet today's high standards, campus housing must address a wide range of concerns including: traditional issues of communal association and privacy; and contemporary issues of communications and technology, social diversity, sustainability and the environment - all these are key influences on residential attitude and surely way of life (Neuman, 2013).

1.1.3 Evaluation of Housing Facilities

An evaluation can be defined as "the process of examining a system or system component to determine the extent to which specified properties are present" (The Free On-line Dictionary of Computing, 2014). As regards housing facilities, "specified properties" are referred to as "performance requirements". Housing performance however should not be limited to the technical expectation but should consider the overall satisfaction of the end users. Regardless of how well specifications have been met and conformed-with in the design and construction of a building, its occupants are only concerned about how well this facility meets their needs (Fatoye & Odusami 2009). Housing satisfaction is defined as the "perceived gap between a respondent's needs and aspiration and the reality of the current residential context" (Varady & Preiser, 1998).

The earliest records of building evaluation studies were notably in the 1960's after World War II in the form of Post Occupancy Evaluations (POE). POE is a tool used to assess successes and failures in a built facility, and has evolved to encompass several techniques and case study applications (Preiser et al., 2015). The main objective of a POE is for the benefit of ‘feed-back’ for effective management of the current housing stock and ‘feed-forward’ to improve planning, design, and construction in future projects (Amole, 2009). A comprehensive approach to POE is by combining multiple techniques to enhance information interpretation and holistic results (Wong & Jan 2003). There exist currently in the field a gamut of techniques and tools. Leaman, 2003 confirms that: “over 150 POE techniques are available worldwide with effectiveness dependent upon the following:

- ✓ Opportunity for benchmarking with results which are easily comparable with previous studies,
- ✓ The time and patience of respondents is not encroached too much,
- ✓ It offers value in terms of quality and content,
- ✓ It is relevant in a given situation,
- ✓ It is reliable by giving similar results when used by different people within similar circumstances
- ✓ Addressing factors related to the needs, activities and goals of the building users”

From the original 'post-occupancy evaluation' (POE) process model developed by (Preiser et al., 1988), a number of researchers have introduced a variety of innovative models. Significant amongst them is the 'Building Performance Evaluation' (BPE) – an integrated framework developed by (Preiser & Schramm, 1997). BPE is a process of continually reviewing the six major phases of the building delivery and life cycle (i.e. planning, programming, design, construction, occupancy and recycling of facilities). The growing concern for Universal Design standards advocated by the American Disabilities Act (ADA) resulted in the development of a framework to evaluate such facilities - the 'Universal Design Evaluation' (UDE) adapted from the previous BPE (Preiser & Ostroff 2001). Other popular models are the Building Use Studies (BUS) and Post Occupancy Review of Buildings and their Engineering (PROBE) technique-both in the United Kingdom. Also, there is the 'Total Building Performance' (TBP) introduced by Hartkopf et al., 1986, in which objective and subjective measurements are made in all performance areas simultaneously and are correlated to achieve holistic results.

1.2 Research Problem

The traditional trend in the product-delivery industry is to design and market products without due consideration for consumers' needs and desires, designers and producers however are not the users of their products (Preiser & Ostroff 2001). For the housing industry in particular, it is well established that re-occurring failure of housing projects is due to the lack of feed-back and lessons-learned derived from the end-users' or occupants' perspective (Jiboye, 2012). This failure cannot be quantified in dollars, as it varies from accidents which lead to fatal injuries or even death. Aside the occurrence of failure, huge investments made in developing housing projects reinforces the need to establish direct communication channels between designers and users through a systematic feed-back technique to ensure quality and value for money (Preiser & Ostroff 2001). Thus the new paradigm is a consumer demand-driven and not supply driven industry (Kim et al., 2005).

Additionally, an inevitable “fine-tuning” process takes place after the completion and occupation of a facility. This is when occupants try to adjust their facilities to suit their needs and thus achieve mutual harmony with the facility. The result is an emphasis on the need to get feedback from the occupants efficiently and rapidly in order to carry out the fine-tuning process (Preiser, 1995). Meir et al., 2009 suggests that to achieve a sustainable outcome it becomes inevitable to conduct a Post Occupancy Evaluation (POE). For surely a building that is not productive cannot be considered as sustainable (Turpin-Brooks & Vicars, 2006).

The greatest efforts made so-far in POE-studies have been in the study of non-domestic buildings, especially offices and educational buildings. Far fewer studies have been carried out for domestic housing facilities (Leaman & Bordass, 2007). Most of the POE-studies that have been carried out fall short in the procedures and techniques employed (Preiser, 1995). A more qualitative approach is needed to achieve a holistic solution. The combination of a variety of techniques while taking into consideration demographics and making environmental observations presents a “rich picture” of the conflicting as well as corroborating viewpoints of the primary stakeholders. The development of such holistic approaches to POE should be given priority in the property sector (Turpin-Brooks & Vicars, 2006).

The King Fahd University of petroleum and Minerals located in a hot and humid climatic region has embarked on the development of a multi-phase campus residential housing project. The latest phase (Al-Marooj) has been completed and occupied by families of a multi-cultural background who have raised concerns about the quality and the performance of their dwellings. This has paved the way for a study to develop a holistic POE-framework which will encompass multiple techniques, demographic characteristics, and a comprehensive questionnaire tool. This tool will be used to evaluate the housing facility to improve the current housing stock and derive feed-forward to improve future housing developments.

1.3 Significance of the Study

While post occupancy evaluation studies number in hundreds, the need for an evaluation to accompany every housing project delivery is established by literature, the following is a list of benefits to be derived from this study:

i. To add to the limited number of studies carried out on family residential estates especially in a university campus.

ii. This study presents a holistic framework which will add to the body of knowledge as a tool that can be used to evaluate family residential estates.

iii. The study also implements the developed framework on a typical case study at King Fahd University of Petroleum and Minerals. Lessons-learned will serve as feed-back for the continuous improvement of the current housing stock and feed-forward for the design, construction and management of future campus residential housing facilities.

1.4 Research Objectives

The primary objective of this research is to carry out a post occupancy evaluation of a family residential housing estate at King Fahd University of Petroleum and Minerals and derive lessons learned for continuous improvement of the existing housing stock and for improved quality in future housing delivery.

Specifically this research aims to:

i. Develop a holistic framework for post-occupancy evaluation of residential housing facilities.
ii. Apply the developed POE framework to a case study of the newly-occupied Al-Marooj Courts at the King Fahd University of Petroleum and Minerals.

1.5 Scope and Limitations

This study is a case-study de-limited to the newly built and occupied 100 housing units "Al-Marooj Courts" which is the first phase of King Fahd University of Petroleum and Minerals faculty residential housing development. The detailed study limitations are as follows:

i. The study will employ a number of evaluation techniques including: walkthroughs, still photographs, environmental observations, questionnaire surveys, interviews and focus group meetings.

ii. Objective measurements will focus only on spot measurements of temperature, relative humidity, air movement, illuminance, ambient noise level, carbon oxide and carbon dioxide level.

1.6 Research Methodology

The research methodology employed is the typical POE process model consisting of the planning phase; conducting phase and applying phase. Figure 1 is a pictorial representation of the methodology.

1.6.1 Phase I: Planning

i. Literature Review which entails:
    a. Reviewing existing literature on housing performance evaluation; its evolution, concepts, approaches and applications/case-studies.
    b. Reviewing literature on objective and subjective methods of assessment
    c. Reviewing POE techniques and frameworks.

ii. Reconnaissance and desk studies which entails:
    a. Meeting and seeking approval and corporation of stakeholders including occupants, consultants, contractors and facility managers
    b. Acquiring project documents, occupancy management records and maintenance work-orders
    c. Acquire instruments and measuring devices

Outcome: the development of a holistic POE Framework methodology and questionnaire tool

1.6.2 Phase II: Conducting

i. Carrying out a walk-through for physical observation and recording with still images
ii. Questionnaire survey
    a. Validate questionnaires with industry professionals and acquire importance ratings of performance indicators
    b. Pilot test the questionnaire survey to ensure clarity and include potential performance indicators
    c. Administer questionnaires to all households
    d. Carry out statistical analysis of results
    e. Carry out spot measurement of CO, CO_2, temperature, relative humidity, air movement, ambient noise level and illuminance and compare to acceptable standards
    f. Conducting a focus group meeting to derive more qualitative feed back

Outcome: Post Occupancy Evaluation results

1.6.3 Phase III: Applying

i. Merge and integrate results of the various techniques employed
ii. Make and validate recommendations through expert consultation
iii. Review recommendations with stake-holders

Outcome: Conclude research with lessons-learned and suggestions for further research

1.7 Structure of the thesis

This study is arranged in the following chapters:

Chapter 1: **Introduction**: This chapter introduces the topic being researched. It provides a statement of problem, research objectives, the scope and limitations, and the systematic methodology employed.

Chapter 2: **Literature Review**: This chapter provides an extensive review on the origin, evolution, techniques and approaches used in Post Occupancy Evaluation and other related concepts. It also presents a review of previous studies.

Chapter 3: **POE Framework and Research Methodology**: This chapter discusses the POE frame work methodology. It also discusses the development of the questionnaire tool and research design and methodology for this study. This includes an overview of the case study and methodology used in walkthroughs, sample size and questionnaire administration, interviews, focused group meetings, physical measurements for Indoor Environmental Quality.

Chapter 4: **Results analysis and discussion**: This chapter will describes the method used for analysis, and discuss and integrate results of different techniques. And also highlight lessons-learned to serve as feed-back.

Chapter 5: **Conclusions and Recommendations**: This chapter provides the main conclusions and recommendations made after review and validation with stake-holders, and also suggest areas for further research.

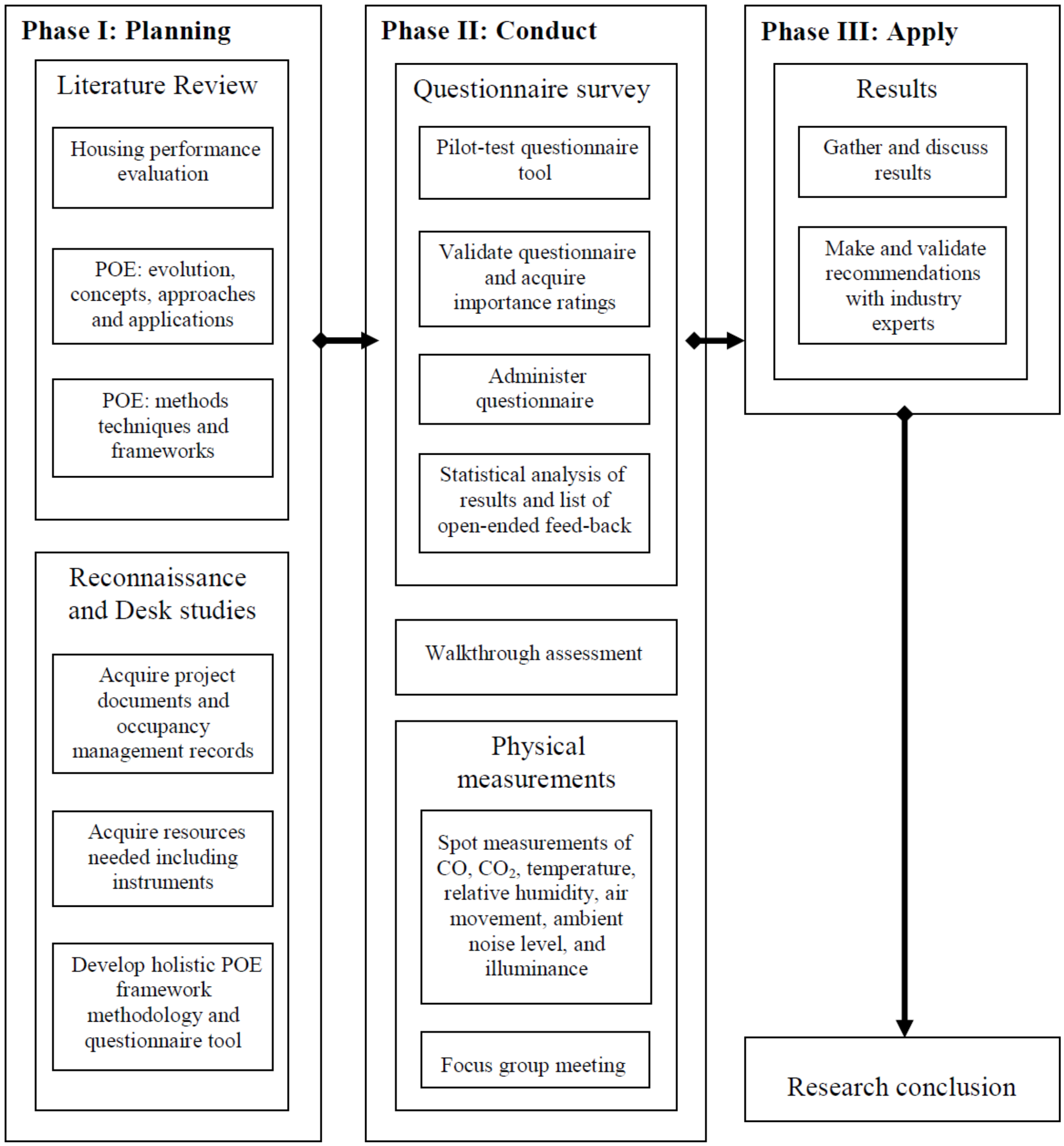


Figure 1. Graphical representation of methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Post Occupancy Evaluation

2.1.1 An Introduction

The term Post Occupancy Evaluation (POE) was coined by building inspectors in the occupancy permit which they issued to confirm that a building was fit for use after its completion (Riley et al., 2010). Post Occupancy Evaluation is however qualified by a wide range of alternative terms (Leaman & Bordass, 2007) including: “Building-In-Use Studies”, “Building Diagnostics” and “Building Pathology” which is becoming popular in the United Kingdom and other European countries. Building Pathology is an expression of the combination between the technical aspects of building performance (structural, mechanical, etc.) and the building performance aspects which focus on the building occupant/end-user. This combination will result in a comprehensive treatment of the subject matter. A more generic term “Building Evaluation” could replace the previous terminologies in the near future (Preiser, 1995). These terms including “Building Appraisal” refer to studies carried out on completed and occupied building projects. They embody a set of procedures used to assess the effectiveness of design decisions made towards ensuring the performance needed by building users (Ilesanmi, 2010). This could be through a systematic comparison of actual performance to required performance, where the difference between the two constitutes the evaluation (Preiser et al., 1988; Jiboye 2012).

POE is generally defined by (Preiser et al., 1988) as “the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time”. Its underlying principle is based on the fact that a systematic study of the relationship between man and his environment is a legitimate aim of building research. Man’s well-being and functionality is intimately linked to the performance of his environment (Hassanain et al., 2010; Li & Lim, 2013). Thus, functionality, comfort and safety are some of the expectations of building users when building performance is discussed (Council, 2001). The residential building in particular is where occupants spend a huge amount of their time and thus should perform exceptionally well to support a wide range of domestic activities (Kim et al., 2005). Hence, POE is given a more specific definition by (Watson, 2003) as “a systematic evaluation of opinion about buildings in use, from the perspective of the people who use them”.

However there are three perspectives to the evaluation of buildings:

- ✓ Occupants, and how well their needs are met
- ✓ Environmental performance, normally energy and water efficiency
- ✓ Whether the building makes economic sense, such as value for money or return on investment (Leaman & Bordass, 2007).

Due to the complexity of a modernised building, its evaluation will cut across an array of technical, functional, social and aesthetic issues (Jiboye, 2012). The study of building evaluation is multi-disciplinary, it spans across professions such as architecture, services engineering and more prominently facilities management. It is also a mix of design, psychology, economics, planning, sociology, and engineering. It is described as “real world research” involving empirical field work through the study of real buildings and real people, though it sometimes involve laboratory research and physical measurement (Leaman & Bordass, 2007).

In a POE study successes and errors are identified, to determine what needs to be repeated and what needs to be avoided in future designs (Watson, 2003), and also to justify requests for renovations, additions or new construction (Preiser et al., 2015). Facility managers use POE as a diagnostic tool and system to identify problem areas in existing buildings, to test new building prototypes and to develop design guidance and criteria for future facilities (Preiser, 1995). The main objective of a POE study is to create a platform to understand the needs and desires of building users and thus provide recommendations to develop more suiting environments to accommodate those needs. So a building or facility manager in order to remain competitive must quantify performance and benchmark with best practices through feedback derived from tenants' needs, concerns, expectations and opinions. Aside users satisfaction, POE fulfil other objectives including: determining building defects; supporting design and construction criteria; supporting performance measures for asset and facility management; lowering facility lifecycle costs by identifying design errors that could lead to increased maintenance and operating costs; clarifying design objectives and improving building performance (Nawawi & Khalil, 2008). Other types of evaluations are conducted that address issues related to operations and management of a facility, such as energy audits, maintenance and operation reviews, security inspections, and programs which have been developed by professional building managers (Khalil et al., 2009).

POE also provides an opportunity for continuous learning of how buildings perform in use, and thus fine-tuning them to perform better (Way & Bordass, 2005). POE results are used to improve specific spaces within a built environment through continued users' feedback, including that of sustainability of the building (Preiser et al., 2015).

POE studies have moved from one-dimensional approach usually based on users' perspectives to a more holistic form of approach (Preiser & Vischer, 2005). Comprehensiveness of techniques in building performance evaluation and monitoring is now considered as a requirement in comparing actual building performance to design expectations. This reveals what needs to be fed back to the construction industry and what should be discarded as bad practice (Nooraei et al., 2013). A holistic approach is also influenced by factors including social, political, organisational and economic forces. POE studies are inevitable if the building industry is to develop, since it provides a base of knowledge from completed projects, drawing on lessons learned (Riley et al., 2010). Building design and construction professionals seldom receive any form of systematic feedback about the performance of completed and occupied buildings, except the comments of disgruntled or satisfied clients. Thus, the need for a systematic feed-back technique to improve building performance cannot be over emphasised (Ilesanmi, 2010).

2.1.2 Origin and Evolution

A bibliography published by the Department of Housing and Urban Development (HUD) claimed to list 700 POEs starting in 1913, this however contained one study with the term "Post Occupancy Evaluation" (Preiser & Nasar, 2008). POE evolved from the architectural programming techniques of the late 1950s and early 1960s (Ilesanmi, 2010). This was as a response to the problems associated with housing needs of disadvantaged groups within the care industry such as institutional care facilities, mental hospitals, nursing homes and correctional facilities. It was also due to issues attributable to the built-environment to improve environmental quality with particular emphasis on the building occupants' perspectives. The performance of both existing and new buildings was assumed to negatively affect the recuperation of residents or inmates. This process was later applied to other government facilities such as military housing, hospitals, prisons and courthouses (Preiser, 1995; Council, 2001; Hassanain, 2008; Riley et al., 2010; Ilesanmi, 2010). The following is a set of common problems associated with building performance as listed by (Preiser, 1995):

- ✓ Health and safety problems;
- ✓ Security problems;
- ✓ Leakage;
- ✓ Poor signage and way finding problems;
- ✓ Poor air circulation and temperature control;
- ✓ Handicapped accessibility problems;
- ✓ Lack of storage;
- ✓ Lack of privacy;
- ✓ Hallway blockage;
- ✓ Aesthetic problems;
- ✓ Entry door problems with wind and accumulation of dirt;
- ✓ Inadequacy of designing space for equipment (like copiers);
- ✓ Maintainability of glass surfaces (e.g. skywalks or inaccessible skylights).

In the 1960s increased interest in research focusing on the relationship between human behaviour and the built environment lead to the formation of a new field of environmental design research. This led to the establishment of interdisciplinary professional associations like the Environmental Design Research Association in established in 1968 (Ilesanmi, 2010). Major players were large organisations with repetitive buildings in english speaking countries. Significant studies carried out were of University dormitories by Sim van der Ryn (1967) of the University of California, Berkeley, and Victor Hsia (1967) of the University of Utah, and Preiser (1969) in his Master's thesis at Virginia Tech (Preiser et al., 2015). Publications on POE techniques, case-studies were further reinforced by proponents of more rational and rigorous design processes in architecture. Christopher Alexander, an early leader in this field, wrote three influential books: Notes on the Synthesis of form (1964), Houses Generated by Patterns (1969), and A Pattern Language (1977). These publications introduced the notion of design requirements and patterns into the design process based upon the evaluation of the needs of those for whom the designs were intended (Preiser et al., 1988).

The 1970s witnessed a dramatic increase in the use of POEs; with significant increase in the scope, number, complexity and magnitude of evaluation studies and publications. Some of these developments include: the use of multiple buildings for data collection and comparative analysis; the use of multi-method approaches to building evaluation; the investigation of a comprehensive set of environmental factors, not as isolated variables, but to access their relative importance to the users of the facilities; and the addition of technical and functional factors to the scope of evaluation studies, compared with the earlier emphasis on strictly behavioural research (Ilesanmi, 2010). By the mid-1970s, the first publications with term "POE" in their title appeared and the very first one was authored by Herb McLaughlin of KMD Architecture in San Francisco in the AIA Journal issue of January 1975. He and a team of consultants had done POEs on hospitals in Utah and in San Francisco (Preiser et al., 2015). The field of POE was defined as "as an appraisal of the degree to which a designed setting satisfies and supports explicit and implicit human needs, and to provide values of those for whom a building is designed" (Hassanain et al., 2010).

By the 80s, a great number of POEs were being carried out in the UK, Canada, New Zealand, Australia, and the US focusing primarily on public works projects, government buildings, airports, office buildings, commercial real estate and a variety of other types of facilities (Council, 2001; Khalil & Husin, 2009; Preiser et al., 2015). By the mid-1980s the National Academy of Sciences (1987) established committees on opportunities for improvement in the practices of programming, post-occupancy evaluation and data base development, which links the two conceptually. Preiser and his colleagues; Rabinowitz and White moved on to publish the first POE textbook in (1988) featuring case-studies and measurement techniques in its appendix. This was followed a year later by another book "Building Evaluation", Preiser 1989, with case studies from around the world (Preiser et al., 2015).

POE strategies and techniques continued to evolve **in the 1990s**, with the sole aim of feed-forward to help building designs and technologies develop. The gradual growth of technology allowed University of Cincinnati to develop a POE database and an expert system compatible with CAD design and facility management databases (Preiser, 1995). In the mid-90s, issues pertaining to the building delivery cycle, as well as the life cycle of a building paved the way for a meta level approach to building evaluation by Preiser and Schramm (1997), and subsequently, an integrative framework/process model for Building Performance Evaluation (BPE) was developed. It encompassed issues like health, safety, security, building codes, functionality and guideline materials. And also the social, psychological, and cultural aspects of building performance. The last three were hitherto ignored in previous POE studies (Preiser & Nasar 2008; Preiser et al., 2015).

The 21st century ushered in new developments in technology and in the construction industry which were previously only imagined. In 2001, a day-long symposium was hosted by the National Academy of Sciences, where the issue of POE was discussed primarily in U.S. Government Agencies. This resulted in a book titled: 'Learning from Our Buildings: A State-of-the-Practice Summary of Post-Occupancy Evaluation'. Also a monograph was written by Preiser 'Improving Building Performance' for The National Council of Architectural Registration Boards (NCARB) for their Professional Development Series; this is to earn recertification/continuing education credit by Architects after being tested on the material. The internet and digital revolution presents the prospects for low cost building evaluation for continuous improvement. Also current world issues including; dwindling non-renewable energy resources, global warming, and sustainable and smart growth development has increased the need for information derived from POE studies (Preiser & Nasar, 2008). Preiser et al., 2015 maintain that it is through the evolution of intelligent buildings that building performance evaluation practices and the study of how technologies and spaces are actually used by the building's occupants continue to develop.

A review of milestones in the evolution and development of POE studies from the 1960s to the 1980s was presented by Preiser et al. 1988, and later updated by Preiser et al, 2015. See appendix A for a table of milestones and contributions to the POE of housing facilities from 1960 – 2015 adapted and modified from Preiser et al., 2015.

2.2 POE Concepts

2.2.1 Levels of Investigation

Based on a series of POEs conducted since the 1970s, it is possible to classify the levels of investigation into three distinct non-cumulative levels according to the amount of time, resources, personnel, the depth and breadth of evaluation, and, therefore, the implicit cost involved in carrying out POEs (Preiser et al., 1988). The levels of effort range from a quick, surface review to a more in-depth investigative analysis, to a diagnostic review correlating physical and occupant perceptions (AUDE, 2006). See table 1. The general approach to each level will involve planning the process, conducting the study and an interpretation of the results (Preiser et al., 1988; Turpin-Brooks & Vicars, 2006). Preiser, 1995 gives an estimation of the cost of these levels of POE effort; indicative POEs cost approximately 50 cents per square foot, investigative POEs cost US$1.75 per square foot, whereas diagnostic POEs can cost anywhere upwards from US$2.50 per evaluated square foot.

Level 1: Indicative POEs; as the name implies gives an indication of major failures and successes of a building's performance (Preiser et al., 1988). It is a broad brush approach where a few interviews are combined with a walk-through of the building. A short, simple questionnaire might also be circulated (AUDE, 2006). This type of POE typically lasts for about two or three hours to one or two days, generally assuming that the evaluating team is well experienced as well as familiar with the building type to be evaluated. Data-gathering methods include: archival and document evaluation; questionnaire surveys; walkthrough and still-photography; and interviews (Preiser et al., 1988).

Level 2: Investigative POEs; is often carried out when an indicative POE has identified issues that require further investigation, requiring about 160-240 man-hours, plus staff time for support services (Preiser et al., 1988). It involves rigorous research techniques and more thorough investigation to derive robust results. Administration of questionnaire will be followed up by focus group meetings and interviews to tease out more qualitative feed-back based on issues identified by the questionnaire responses (AUDE, 2006). Evaluation criteria are established through state-of-the-art literature review (Preiser et al., 1998). Evaluation can be accompanied by photographic/video recordings, and physical measurements, and involve a number of typical buildings (Preiser, 1995).

Table 1. POE levels of investigation (As is: Turpin Brooks and Vicars, 2006)

Level of POE	Aims	Methods	Timescale	Comments
Indicative	Assessment by experienced personnel to highlight POE issues	Walk through evaluation. Structured interviews? Group meetings with end-users? General inspection of building performance? Archival document evaluations?	Short inspection period	Quick, simple, not too intrusive/disruptive to daily operation of building. Judgmental and overview only?
Investigative	In-depth study of buildings performance and solutions to problems	Survey questionnaires and interviews. Results are compared with similar facilities. Report appropriate solutions to problems.	From one week to several months	In-depth/useful results. Can be intrusive/time-consuming, depending on the number of personnel involved.
Diagnostic	Show up any deficiencies (to rectify and collect data for future design of similar facilities	Sophisticated data gathering and analysis technique. Questionnaires, surveys, interviews and physical measurements	From several months to several years	Greater value in usability of results. More time consuming.

Level 3: Diagnostic POEs; these are comparable to traditional and in-depth research with a specified scope and limit, requiring more time to complete, usually several months to a year or more. It employs the use of more advanced data gathering techniques and sophisticated instruments, dealing with issues like stair safety, orientation and way finding, artificial versus full spectrum lighting, privacy, overcrowding, etc.

(Preiser, 1995). A thorough analysis is made which combines occupants' responses to the performance of building environmental systems including: air-handling, lighting, energy use, heating, measuring ventilation rates, temperature, lighting levels, energy use, CO emissions and acoustic performance (AUDE, 2006). The results and recommendations derived from this kind of study are long-term and serve as feed-back not for a single facility, but for a given building type (Preiser et al., 1988).

2.3 POE Frameworks and Models

Performance evaluation studies (both measured and perceived) are characterized by a systematic investigation of opinions, perceptions, and viewpoints about built environments in use from the perspective of the users (Preiser et al., 2015). Building performance analysis can be studied from three different perspectives: occupants' perceptions; environmental performance; and economic value. Occupants' perspective towards the performance of buildings is based on the extent to which the building fulfils their needs and desires and how well they are able to carry out their activities in it. Environmental performance depends on the assessment of energy and water efficiency. Economic value is a measure of how much economic sense the building makes; the value for money or return on investment (Ng et al., 2013).

Stakeholders' responses are measured with the use of likert rating scales ranging from very satisfied to neutral to very unsatisfied; this could be as low as a 3-point to as much as a 7-point scale. Questions are presented in the form of surveys which are administered in hard copy formats or via the internet. Also environmental attributes are weighted by a panel of laypersons and expert judges based on the premise that not all evaluation criteria carry equal weight (Preiser et al., 2015). POE encompasses the most comprehensive building performance analysis from occupants' perspective, where the variables of instruments involved are questionnaire, interview, and observation related to occupants' perspective, and the period of assessment carried out is for after occupancy (Ng et al., 2013). Benchmarking with occupants responses presents a huge potential for POE to improve the performance of a building (Ilesanmi, 2010).

A process model was developed for POE based on a critical study of a number of researches by Preiser et al., 1988. This process model illustrated in figure 2 consists of three phases and nine steps which a typical post occupancy evaluation goes through.

Buildings and the people that use them are very complex, and thus interact together in many different ways demanding proper selection of POE techniques. Baird et al., 1996 published a review of over a hundred techniques carried out in the 1990s. POE approaches are selected based on the unique needs and objectives of those conducting the evaluation. As a rule of thumb POE techniques should be selected to: give results which are easy to compare with others; avoid intruding on the respondents time and patience too much; give good value in terms of quality and content; be relevant in a given situation; be reliable i.e. give roughly the same results when used by different people in similar circumstances; and address the factors that relate to the needs, activities and goals of the people using the building (Turpin-Brooks & Vicars, 2006). POE experts utilise available knowledge, techniques and instruments which continue to evolve. The goal however is to help technologies and design to develop by sharing and comparing findings (Preiser et al., 2015).

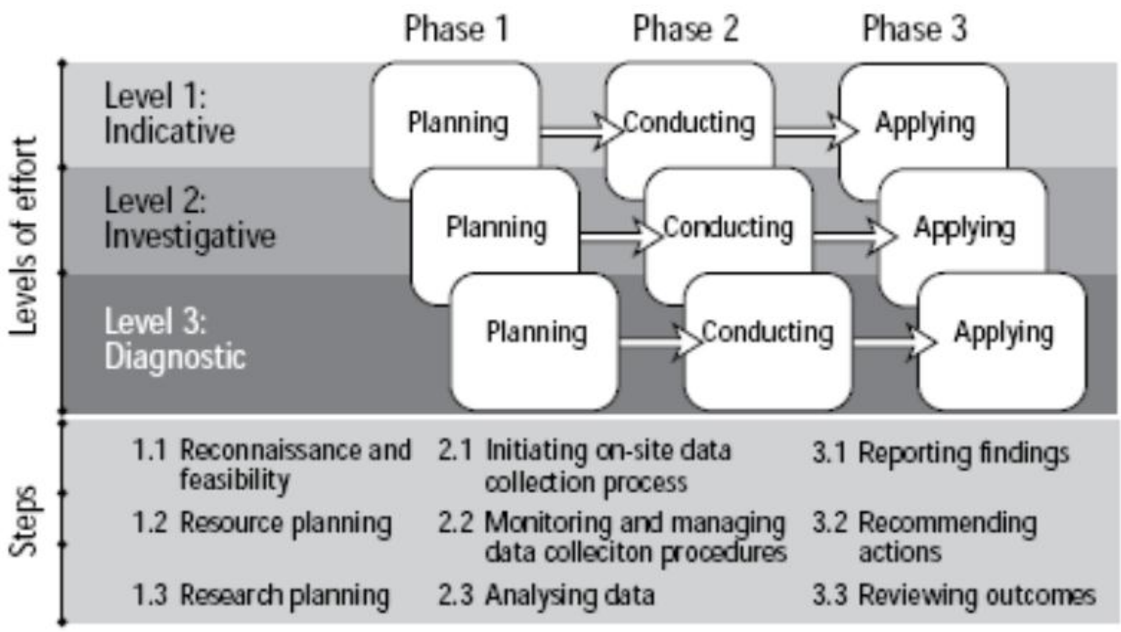


Figure 2. POE process model (As is: Preiser et al., 1988)

The early POE process model developed by (Preiser et al., 1988) in figure 2 is considered quite simplistic and in many ways inadequate. This was realised by Preiser & Schramm in the mid 1990's and thus their investigation and subsequent development of an integrative framework/process model for building performance evaluation to deal with issues particular to the building delivery cycle and life cycle of a building. This framework is meta-level approach in which post-occupancy evaluation represents only one of six internal review loops (Preiser et al., 2015). A short review of established POE methods is presented in table 2.

2.3.1 POE Models for Sustainability

The growing concerns for sustainability lead to United States Green Building Council (USGBC) launching the first formal framework for rating green buildings in the US: Leadership in Energy and Environmental Design (LEED). The rating system's structure consists of five categories: sustainable sites, water efficiency, energy & atmosphere, materials & resources, and indoor environmental quality (IEQ). Most of the POE studies of green buildings however have focused on more easily quantifiable criteria such as energy use and physical measurements of environmental conditions, which at best give an indirect assessment of how the building is affecting the occupants (Abbaszadeh et al., 2006).

Other tools that have been developed to address the issue of sustainability include: Green building assessment tool GBTool and BREEAM, they are regarded as significant contributions to the field of building performance assessment. GBTool was developed as part of the international Green Building Challenge Project, focusing on three building types: school, multi-family residence, and small-scale office building. It can be used internationally, while accounting for regional or national conditions. The scoring system that ranges from –2 to 5 was established, with level 0 being the benchmark level, set by regulations or industry norms. BREEAM, developed in UK, is one of the most widely known means of reviewing and evaluating the environmental performance of buildings. The three models present a typical evaluation of building environmental performance to meet sustainability goals, and also present certified rating systems for new or existing buildings (Kim et al., 2005).

In Canada, a building performance evaluation protocol has been developed by EcoSmart. The protocol has been piloted on six buildings and is publicly available to the design community, including a version that has been adapted for multi-unit residential buildings. However, no details are provided on the costs involved (which are likely to be significant since the protocol draws on the expertise of an acoustics consultant, an indoor air quality consultant, a lighting consultant and a controls and commissioning consultant). Also, the protocol calls for the use of a survey to assess occupant satisfaction, but the survey itself is not included in the scope of the protocol (Taylor et al., 2010).

2.3.2 POE Models for Quality

The housing quality indicator (HQI) system was developed in 1998 in the UK as a measurement tool to assess quality of key features of a housing project in three main categories, which are Location, Design, and Performance. These three categories produce the 10 quality indicators that look not only at the housing unit and its design in detail, but also the context and surroundings, and aspects of performance in use. The HQI system can be updated as basic standards evolve and adapted over time to meet new circumstances and varied needs (Kim et al., 2005).

Also the Construction Industry Council Design Quality Indicators (CIC DQIs) developed in collaboration with the University of Sussex. It is a questionnaire designed to gather feed-back from a diverse range of people affected by the building at any stage of the building life cycle. Respondents can include occupiers, local residents and even passersby. For educational buildings it is most effective when a number of buildings are considered in the study. The self-completion questionnaire consists of approximately 100 questions on a 6-point likert scale, hence of a time-consuming nature (Turpin-Brooks & Viccars, 2006).

Other quality assessment tools are QUALITEL certification system of France which guarantees the performances of various technical equipment in the habitation; and QUARQ in Portugal which measures the degree of adequacy between the architectural characteristics of housings and occupants' needs and expectancies (Kim et al., 2005).

2.3.3 POE Models for Higher Education Buildings

Relating more specifically to university housing context Hassanain et al., 2010 presents a generic framework which entails:

- carrying out a walkthrough investigation,
- organising focused group meetings,
- interviewing the executives of campus maintenance and planning departments,
- developing and administering a questionnaire survey,
- organising a public hearing session,
- analysing the data gathered from the above, and
- Recommending a range of time-phased solutions for housing improvements.

They tried to distinguish their framework by pointing out two of its major qualities which is: a diversified investigation technique, integrating community participation and lastly its applicability to a network of buildings contrary to previous studies that had focused on single buildings. This framework is not without short comings since it relies only on subjective methods of evaluation.

Temple, 2014 recommends the use of HEDQF (Higher Education Design Quality Forum) tool or the AUDE (Association of University Directors of Estates) post-occupancy toolkit for university buildings. This is to encourage the creation of buildings that meet or exceed user expectations, contribute to the immediate surroundings, promote a sense of community and social interaction, are economic to maintain and run, future-proofed, environmentally appropriate, provide value for money, and are constructed on time and within budget. While all educational buildings are encouraged to use BREEAM Education tool to ensure they are environmentally sound or BREEM In-Use or BREEAM Refurbishment.

The Higher Education Design Quality Forum (HEDQF) jointly developed by RIBA and the Higher Education Funding Council for England (HEFCE) formed in 1995. The objective of the HEDQF is to specifically improve the performance of buildings and estates within universities and higher educational colleges. The major component of this review is the "De Monfort" approach to POE, due to its development within the De Monfort University in Leicester. It is carried out one year after occupation and is made up of seminars and a series of intense interviews, and data collection methods with stakeholders that have been involved in the briefing, design, construction, occupational and management of the building (Riley et al., 2010).

Table 2. Established POE methods (Source: modified AUDE, 2006)

Method/Model/ Framework	Format and techniques used	Focus	How long does it take?	When is/can it be used?
De Montfort method	Forum Walk-through of the buildings	Broadly covers the process review and functional performance	1- day generally	A year after occupation
CIC DQIs (Design Quality Indicators)	Questionnaires	Covers functionality, building quality and impact	Questionnaire completion is online -takes about 20-30mins. Analysis is immediate	At design stage and after completion
Overall Liking Score	Questionnaire: -hard copy -web based 7 point scale	Occupant Survey sections include educational Diagnostic tool	10 minutes for each occupant	About 12 months after occupation
PROBE	Questionnaire Focus groups Visual surveys Energy assessment Env. Performance of systems	User satisfaction/occupa nt survey -Productivity Systems Performance Benchmarks developed	Overall process varies time needed 2 days (over two months?) One-person month	Anytime but PROBE team recommend earliest at 12 months
BUS Occupant Survey	Building Walkthroughs Questionnaire backed up by	Occupant satisfaction Productivity	10-15mins to complete questionnaire	On its own or in conjunction with other methods. Anytime but often

	focus groups			after 12 months
Energy Assessment and Reporting methodology	Energy use survey Data collection e.g. from energy bills	Energy use and potential savings	Full assessment up to one-person week	Once building id completed. On its own or in conjunction with other methods e.g. PROBE

A POE guide was published in 2006 by the Association of University Directors of Estates (AUDE) developed jointly with the University of Westminster and support from HEFCE. Its main purpose was to make benchmarking, management and operation of educational buildings more precise, to be specifically used by Higher Education staff and professionals working on educational buildings. It has an extra advantage in considering the life cycle of the building and has approaches to suit each stage while still placing the responsibility on estates professionals (AUDE, 2006).

2.3.4 POE Models in the UK

In recent POE studies of UK housing, research methods have incorporated detailed studies of physical building performance, qualitative evaluation of occupant perception and behaviour and a combination of these approaches. Examples of this include an Energy Saving Trust (EST) protocol for monitoring the energy and carbon performance of new dwellings and a Commission for Architecture and the Built Environment (CABE) survey of residents‟ attitudes to the design of new housing (Taylor et al., 2010).

Also is the Building Use Studies (BUS) occupant survey developed by BUS Ltd. alongside the Building Research Establishment (BRE). It has been in use for over 20 years with applications on non-domestic buildings with permanent occupants, offices, higher educational buildings, and schools, with adaptations also available for students and visitors. Thus, a database of results has been established to compare results against other benchmarks. (Riley et al., 2010). Key Performance Indicators (KPIs) used for this questionnaire are limited to 12 topics covering aspects such as physical conditions within the environment (lighting, temperature, noise and air movement), personal control over the physical conditions, management response to complaints, health and overall comfort productivity, as well as background and overall quality of the building. For the sake of comparison of results to other studies, the questions are standardised and in some cases may not be relevant to the case at hand. A version of the questionnaire for domestic buildings has also been developed.

Another study which was a follow-up to "BUS" was the Post-Occupancy Review of Building Engineering (PROBE) studies funded by the UK Government and The Builder Group. This was a research project spanning from 1995 to 2002, and publishing the results of 20 POE's within this period, and a number of review papers, one of which was the special issue of Building Research and Information (2001). It was the first to publish its results in the UK, thereby setting a precedent for future publications. PROBE's main aim was to create a public domain to assist designers and clients by gathering results from previous POEs qualitatively and quantitatively. Tools like the TM22 energy survey method combined with BUS occupant survey as well as interviews, walkthrough observations, and review of technical issues were used. One major distinction of the PROBE studies was its tackling of sustainability and energy performance issues, though all sustainability indicators and occupation styles were not taking into consideration (Riley et al., 2010). The energy survey method developed for Probe is now published as a CIBSE guide. However, the occupant survey method is only available under licence from Building Use Studies (Taylor et al., 2010).

Overall Liking Score (OLS) was also developed in the UK by ABS consulting, in collaboration with the University of Manchester Institute of Science and Technology. Its aim was to address the three objectives of sustainable development including economic, social and environmental issues. The approach obtains feedback about the successes and concerns from building occupants. Additionally, (Key Performance Indicators) KPIs are measured to assist maintenance and other FM services. Over 25 studies using this approach has been carried out in the UK, 6 of which were in the educational sector to support improvements through Facilities Management (Riley et al., 2010).

2.4 Benefits of POE

A POE can answer the following questions: does the facility support or inhibit the ability of the institution to carry out its mission? Are the materials selected safe (at least from a short-term perspective) and appropriate to the use of the building? In the case of a new facility, does the building achieve the intent of the program that guided its design? Generally POE provides real information to serve as the basis for decisions geared towards improvements in the current housing stock and about the design and development of future housing projects (Amole, 2009; Zimmerman & Martin, 2001). The idea of post occupancy evaluation ensures accountability and responsibility on the part of housing managers, designers and policy makers (Menzies & Wherret, 2005; Amole, 2009). The building's physical evaluation is feared most by the building's architect: "the fear of what you might discover." He fears that a law-suit is the consequence of a building evaluation, although the effective use of a POE is more likely to prevent a lawsuit (Preiser et al., 2015)

Some of the beneficiaries of a POE study include: designers wanting to avoid past mistakes; educators passing the knowledge on to students; existing and prospective building owners, occupiers, developers and managers; and policy makers looking for the best way forward (Leaman, 2010). The benefits of POE are numerous as it is in itself the precursor to a sustainably built environment as pointed out by (Meir et al., 2012). Khalil et al., 2009 also points to the fact that through a POE study much ideas and solution are developed to achieve buildings' sustainability. Preiser et al., 1988 divide the benefits of a POE study into three as follows:

- **Short-term benefits**: that is immediate problem solving through identifying problems in buildings and proffering appropriate solutions.
- **Medium-term benefits:** that is feed forward of the positive and negative lessons learned into the next building cycle.
- **Long-term benefits**: these involves the creation of databases, clearing-houses and the generation of planning and design criteria for specific building types, such as health-care facilities, offices, etc.

2.4.1 Continuous Improvement

Zimmerman & Martin, 2001 state that "the over-arching benefit from conducting POEs is the provision of valuable information to support the goal of continuous improvement". This information gained carries significant value for all stakeholders involved within the project lifecycle (Riley et al., 2010). By providing an indication of successes and failures in a building's performance, improvements can be made over the building's life cycle (Menzies & Wherret, 2005). Some of the objectives a POE is used to fulfill over the life cycle of a building are: determining building defects; supporting performance measures for asset and facility management; lowering facility lifecycle costs by identifying design errors that could lead to increased maintenance and operating costs; clarifying design objectives and improving building performance (Nawawi & Khalil, 2008). A POE study also ensures the provision of the right environment to support the building users' needs and aspirations (Ilesanmi, 2010). Improvements in aesthetic quality and indoor environment are not the only potential benefits the results of a POE study presents, rather minimising energy consumption can also be achieved through significant savings on maintenance and operation costs (Jamaludin et al., 2013).

2.4.2 Feed-Forward to the Construction Industry

Major outcomes and benefits of evaluations studies were the development of guidelines for the planning and design of future buildings (Preiser et al., 2015). POE provides the potential benefit of improving the knowledge and practices of clients, designers, builders, facility managers and other built environment professionals (Taylor et al., 2010). As a result of insights POE provides into the outcomes of past design decisions and the resulting building performance, it forms a good background not only for improving existing buildings, but for the design, construction and operation better buildings in future (Hassanain et al., 2010). The cornerstones for continuous improvement sought by the higher education sector remain evaluation and feedback (AUDE, 2006).

2.5 Barriers to the implementation of POE

Though POE studies have lasted over five decades featuring various research and case-studies, there are still hindrances in the implementation of POE studies or in feed-back should such studies be carried out. Leaman et al., 2010 state that "lessons are still not learned in spite of the crying need to close the feedback loop and get our buildings performing radically better. Obviously something is systematically wrong". If the benefits of POE are well recognised, then why has it not been fully implemented? Or adopted as part of the standard procurement process of buildings? The following are some of the barriers to the implementation of POE recommendations:

2.5.1 Cost and Ownership

Neither the client nor the project team consider the cost of POE as part of their budget (Turpin-Brooks & Vicars, 2006). The concept of continual improvement is not recognised in standard practice of the facility delivery process. The proof for this is that designers are almost never paid to go back and review the outcomes of their design decisions (Zimmerman & Martin, 2001). Professionals are reluctant to become liable for the associated costs. On the part of the client, he believes that any activity to ensure the full and efficient operation of the facility has already been paid for. It will take a detailed assessment of the costs and benefits to make a client pay extra for an evaluation (Riley et al., 2010).

2.5.2 Standardization of POE Methods

Different stakeholders in the industry do not agree on a set of performance indicators to define what constitutes a good building. This need for better building performance indicators has been recognized by many researchers including the participants in the US Department of Energy's Commercial Whole Buildings Technology Roadmap process. The PROBE process was a significant step in reducing barriers and unifying the process to create a set of usable data for benchmarking (Zimmerman & Martin, 2001). POE methods need to be standardized across the industry to provide compatible results that can be compared to give indications of improvement (Turpin-Brooks & Vicars, 2006).

2.5.3 POE Results

If negative results are envisaged by managers, a POE study can be opposed or even sabotaged (Turpin-Brooks & Vicars 2006). For rented apartments which are fully let out, owners will be reluctant to endorse such a study that could potentially uncover shortcomings in their buildings and effectively reduce its market value in a competitive market. And thus tenants would move out resulting in loss or reduction in revenue (Zimmerman & Martin, 2001). The same applies to the project team, who fear that the results of the POE would unearth results that deem the building ineffective, and the project ultimately unsuccessful (Riley et al., 2010). Due to this, POE results are not published, and thus mistakes are not learnt by designers, while managers and others commissioning buildings ignorantly help perpetuate the same mistakes (Leaman et al., 2010). The use of sophisticated statistical techniques could also make interpretation of the occupancy survey results difficult (Turpin-Brooks & Vicars, 2006) and thus less likelihood of its adoption as feed-back or feed-forward.

2.5.4 Insufficient Knowledge and Training

It is likely that many clients, design team members and building users have not heard of POE (Zimmerman & Martin, 2001). Construction professionals are only trained and experienced in creating buildings, contrary to expectations that they have an in-depth knowledge of building performance (Riley et al., 2010). The curriculum for traditional design education has no provision for POE to be taught, POE training is mostly acquired by social designers or through research (Zimmerman & Martin, 2001). Training needs to be given more emphasis to promote the benefits of POE and overcome its barriers (Turpin-Brooks & Vicars, 2006). With growing interests in improving their facilities and ensuring occupants wellbeing and performance, coupled with latest technological advancements hence reduced cost, POE seems to be taking a more serious turn (Bordass & Leaman, 2005).

2.6 Previous Studies

Although hundreds of POE studies have been carried out on a variety of facilities since the 1960’s (See Appendix A), most of these studies have been geared towards non-domestic buildings including: medical facilities; commercial and educational buildings. For college and university campus facilities in particular, research has been geared towards classrooms, student housing facilities, library and research facilities. A review of literature shows that domestic housing facilities within or outside campuses started to receive significant attention of researchers in about the last five years. Examples of studies carried out in domestic housing facilities include:

Kim et al., 2005: presented the development and application of a computer model for housing performance evaluation for multi-family residential buildings in Korea, their goals was to encourage initiatives towards better housing performance and to support a homebuyer's decision-making on housing comparison and selection. They identified forty-one objective and feasible performance indicators based on the review of literature and expert-interview, and then classified into: "housing environment" including; location, surroundings and site; "housing function" including: spatial plan and usability; "housing comfort" including: thermal comfort, acoustic comfort, visual comfort and indoor air. These indicators were thus weighted using the Analytical Hierarchy Process (AHP) analysis, and the weights converted to credits; this is in contrast to other studies that assume all indicators are of equal weight and importance. Their study however is restricted to the specific Korean context.

In contrast to (Kim et al., 2005)'s objective assessment model, Fatoye & Odusami, 2009 argued for a more occupant oriented housing performance evaluation. Occupants' main concern is how the constructed facility will best meet their needs and expectations regardless of how the construction has conformed to specifications. Thus they used indicators of HOMBSAT instruments of building performance, to evaluate housing performance and assess the relative importance of the performance indicators as perceived by the occupants. 70 quality performance criteria categorised into four sub-systems including: "the design", "the house", "the estate layout" and "site location as well as ease of access to local facilities and city wide services". These were gathered in a questionnaire survey with a 7-point likert-type scale ranging from 1 (very dissatisfied) to 7 (very satisfied). Direct field observation was also used. They concluded that occupants were most satisfied with criteria under design such as the number of rooms in their houses, the ceiling height, the location of different rooms, and nearness to religion (worship) location. They were least satisfied with the criteria under the subsystems of estate layout and site location, and access to local facilities and city-wide services such as nearness of house to fire-fighting stations. And finally concluded with a recommendation of improved maintenance of housing essential facilities.

Ilesanmi, 2010 conducted a study to evaluate the residential environments of five low-income and three medium-income public housing estates in Lagos, Nigeria. He employed expert ratings of four evaluators with ten performance criteria developed to assess the physical characteristics of the residential environments including: external visual quality of buildings, maintenance quality of buildings, structural quality of buildings, detailing quality of buildings, quality of building services, quality of estate roads, quality of landscaping, quality of semi-public open spaces, quality of environmental layout and quality of location. An occupancy survey questionnaire with a 5-point Likert scale was also used to assess occupants' residential satisfaction; he also examined the socio-economic (demographic) characteristics of the occupants. Descriptive and inferential statistics were used for data analysis, thus showing a 62 per cent correlation between physical characteristics of the residences and residential satisfaction.

Mohit et al., 2010 assessed the residential satisfaction of occupants of a newly designed public low-cost housing in Kuala Lumpur, Malaysia. A list of 45 variables grouped into five components including: dwelling unit features; dwelling unit support services; public facilities; social environment and neighbourhood facilities. Their analysis with a Multiple Linear Regression (MLR) model suggested that residential satisfaction of public low-cost housing can be enhanced through improving the management of security control, perimeter roads, cleanliness of garbage house and garbage collection by the local authority. Their study also pointed out the improvement of housing design in terms of its spatial requirements and number of rooms will improve residential satisfaction. They pointed out that the demographic characteristics of the resident such as age, family size, working wives, previous residence are negatively correlated with residential satisfaction, whereas residents' race, employment type, floor level and length of residency are positively correlated with residential satisfaction. They concluded by recommending improvement in management of public and support facilities and building different sizes of housing units to suit families of various sizes.

Another study in Lagos Nigeria was carried out by Jiboye, 2012 similar to Ilesanmi, 2010. He mapped out the demographic characteristics of the respondents and used a questionnaire survey to evaluate occupants' satisfaction based on a 3-item rating scale: (1) dissatisfied; (2) neutral; and (3) satisfied. The evaluation of dwellings' physical characteristics and residential environment was done using a 10 performance criteria. Performance indicators include: functional issues of housing type, accessibility, car parking provision, adequacy and efficiency of services, building density, landscape and children playing spaces, aesthetic issues of visual quality and spatial configuration; technical issues of structural soundness, behavioural issues of privacy and level of security, and sense of community. He employed the use of descriptive statistics and the Pearson Chi-square test in determining the significance of identified physical characteristics on residential satisfaction (with probability level $p<0.05$). His results confirm the relationship between the quality of certain physical characteristics in the housing environment and the occupants' satisfaction. He concluded that a good number of residents were generally satisfied with their dwellings and estate neighbourhood in terms of functionality, accessibility, spatial adequacy and efficiency, aesthetics, security, privacy and sense of community among several others.

Hassanain et al., 2010 presents a framework for evaluating the quality of university family housing facilities. They argued for a difference between the quality of life and quality of place of the occupants. Their framework featured multiple techniques including: a walkthrough investigation; focused group meetings; interviewing the executives of campus maintenance and planning departments; developing and administering a questionnaire survey; conducting a public hearing session; analysing the data gathered from the above; and recommending a range of time-phased solutions for housing improvements. They also emphasised on the advantage of their framework in its use for a network of buildings and not single buildings like previous POE frameworks.

Nooraei et al., 2013 carried out a study of an award winning, as designed low-carbon and affordable apartment building in Swansea, UK. This consists of 69 apartments (6 one bedroom and 63 two bedroom) over six storeys. Their methodology was a combination of Semi structured interviews for the occupants, design and construction team; and physical monitoring of the internal conditions of three apartments. The questionnaires used were administered to occupants responsible for paying the home's utility bills (adults over 18 years of age only). And a Likert scale was used with seven categories from "poor", "unsatisfactory" or "uncomfortable" to "good", "satisfactory" or “comfortable”, including a “neutral” category. Also, further comments could be provided for some of the issues already raised in the survey and their perception of their apartment and the apartment building. Issues assessed in the questionnaire relate to comfort, water use, noise, daylight, household bills, health, behaviour, home management and maintenance; and also their general comments about the apartments. Spot measurements were taken before and after each interview to record the air temperature, carbon dioxide levels, solar radiation, air movement and daylight levels in each apartment, on the exterior balcony, in the circulation corridor immediately outside the apartment, the stairwells and exterior to the building at street level. Questionnaire surveys revealed issues such as high indoor air temperatures, inadequate ventilation, lack of daylight, lack of cold water and lack of a proper induction.

Inah et al., 2014 studied the residential satisfaction of the urban poor in Calabar, Nigeria. A questionnaire survey of 250 households selected from 593 houses across 11 wards in the metropolis was conducted. They emphasized in their study the need to study the influence of behavioural, economic, functional and timing characteristics of housing satisfaction in addition to physical and environmental quality attributes, in contrast to many studies that focus on the Indoor Environmental satisfaction of occupants. 24 basic satisfaction attributes were included in the survey on a five point Likert scale; 5 for extremely satisfactory, 4 for very satisfactory, 3 for satisfactory, 2 for unsatisfactory and 1 for very unsatisfactory. Performance elements addressed in the study include: environmental elements; functional elements; behavioural elements; economic elements; timing elements. 211 (71.7%) responses were judged to be valid and thus used for analysis. Their results reveal a high level of dissatisfaction with accessibility to environmental facilities, pollution services and prompt attention paid to house maintenance.

Table 3. A review of techniques and research focus of previous studies

Study	Techniques	Focus	Description
Kim et al., 2005	Computer model based on objective inputs	Covers -housing environment -housing function -housing comfort	This study is specific to the Korean context, and is solely based on objective assessments and technical specifications. It is intended to support home-buyers decision-making not occupants' satisfaction for consequent improvement of housing stock.
Fatoye & Odusanmi, 2009	Questionnaire survey -hardcopy 7 point likert scale Field observations	User satisfaction of building quality and functionality and estate quality	Study focuses only on occupants' perspective and does not explore deeply Indoor Environmental Quality. Importance ratings are not real life experts' feed-back.
Ilesanmi, 2010	Expert ratings Demographic characteristics Occupant survey -hardcopy 5-point likert scale	User satisfaction of building physical characteristics	IEQ is ignored and the focus is on occupants' perspective on behavioural issues of quality. Importance ratings are based on real life experts' feed-back
Jiboye, 2012	Demographic characteristics Occupant survey -hard copy 3-point likert scale	Broadly covers building functionality	The study's main focus in on functional and behavioural issues. Technical issues are restricted to structural integrity and security. A narrow 3-point likert scale also inhibits the derivation of richer responses.
Nooraei et al., 2013	Questionnaire survey -occupants -design team -construction team	Strongly focuses on Indoor Environmental Quality	Study focuses on IEQ and ignores the functional and behavioural aspect of the building.

	Physical monitoring 7-point Likert scale		
Inah et al., 2014	Demographic characteristics Occupant survey -hardcopy 5-point likert scale	User satisfaction of building physical characteristics and some environmental parameters	Indoor Environmental Quality is not explored deeply. All performance indicators are assumed to carry equal weight. The study is also limited to occupants' opinion survey.

Thus far, most of the POE-studies that have been carried out fall short in the procedures and techniques employed (Preiser, 1995). A tabular review of techniques and focus of previous studies is presented in table 3. It is apparent that most of the studies previously carried out on domestic housing facilities are limited to few number of techniques and so are not comprehensive. These studies can also be described as impartial. Only very few studies take into consideration demographic characteristics (or background) of respondents. As regards the performance element and indicators investigated in these studies, they are skewed towards one of the three major categories identified by Preiser et al., 1988 (i.e. technical, functional and behavioural). Alternative terminologies was used by other researchers like Kim et al., 2005 classified the indicators under Housing Comfort, Housing Function, and Housing Environment, while Fatoye & Odusanmi, 2009 classified the indicators under five broad categories including: Design; The house; Estate layout and site location; and Ease of access to local facilities and city wide services.

Figure 3, 4 & 5 illustrates the performance elements considered in these previous researches. None of the previous researchers have gathered all performance elements comprehensively. A more qualitative approach is needed to achieve a holistic solution;

combining a variety of techniques; taking account of demographics and environmental observations; combined with a comprehensive list of indicators. This will give a “rich picture” of the actual performance of the building, and thus a holistic approach desired in the property industry.

Category	Study	Elements
Technical Performance Elements	Kim et al., 2005	Thermal Comfort, Acoustic Comfort, Visual Comfort and Indoor Air
	Fatoye & Odusanmi, 2009	IAQ, Security, Performance of Foundation, Performance of Roofs, Ease and Cost of Maintenance, Security, Water Pollution, Noise Pollution and Source of Water.
	Ilesanmi, 2009	Maintenance Quality of Buildings, Structural Quality of Buildings and Detailing Quality of Buildings
	Jiboye, 2012	Structural Soundness and Level of Security
	Nooraei et al., 2013	Comfort, Water Use, Noise, Daylight, Household Bills, Health, Home Management and Maintenance
	Inah et al., 2014	Free ventilation, Noise pollution, Water pollution, Air pollution, Security level of the house, Easiness of maintenance of house, Frequency of house maintenance

Figure 3. List of performance indicators from previous studies (Technical Performance Elements)

Category	Study	Elements
Functional Performance Elements	Kim et al., 2005	Spatial Plan and Usability
	Fatoye & Odusanmi, 2009	Space, Layout, Floor Plan, Accessibility, Number and Position of Controls, Operation of Windows, Doors, Electrical and Plumbing Fittings, Parking, Drainage and Disposal System, Street Lightning, Parks and Open Spaces.
	Ilesanmi, 2009	Quality of Building Services
	Jiboye, 2012	Accessibility, Parking, Adequacy and Efficiency of Services. Building Density, Landscape, Children Playing Spaces, Spatial Configuration
	Inah et al., 2014	Availability of good road, Drainage system, Waste disposal system, Position of different rooms, Parking space, Functionality in design, Size of rooms, Electrical fixtures, No. of rooms, Toilet and bathroom available, Operation of doors, Roof performance, Quality of building materials, Quality of building materials, Storage space, Ceiling heights

Figure 4. List of performance indicators from previous studies (Functional Performance Elements

Category	Study	Elements
Behavioural Performance Elements	Kim et al., 2005	Location, Surroundings and Site
	Fatoye & Odusanmi, 2009	Privacy, Nearness to Friends, Space for each member, Plot Size, Building Set-Back, Aesthetic Appearance, Colour, Landscaping; Ease of Access to Local Facilities and City Wide Services
	Ilesanmi, 2009	Maintenance Quality of Buildings, Structural Quality of Buildings and Detailing Quality of Buildings
	Jiboye, 2012	External Visual Quality, Privacy and Sense of Community
	Nooraei et al., 2013	Behaviour
	Inah et al., 2014	Proximity to place of worship, Building setbacks, Physical appearance, proximity of house to police station, Proximity of house to hospital, Proximity of house to fire station, Extent of social relation among neighbors, Proximity to school for children, Proximity of house to market, Proximity of house to workplace

Figure 5. List of performance indicators from previous studies (Functional Performance Elements)

CHAPTER 3

POE FRAMEWORK AND RESEARCH METHODOLOGY

3.1 Introduction

There exist currently in the field a gamut of techniques and tools; according to (Leaman, 2003) - over 150 POE techniques are available worldwide. Most of the POE studies have relied heavily on occupants responses alone which are sometimes over-exaggerated as proven by studies through Instrumental measurements of building's indoor environment. Thus POE based on occupant responses alone is insufficient in evaluating building performance (Deuble & de Dear, 2014). Leaman et al., 2010 state that what is currently absent from housing evaluation in the UK is an overall methodology for assessing energy and carbon performance and user satisfaction and a framework for making feedback routine within the briefing and development process.

The need for such holistic and comprehensive methodology is not restricted to the specific UK context; rather it is a need for the housing industry in general. Kim et al., 2005 opines that a more objective and consistent evaluation of residential buildings requires a comprehensive performance evaluation model that considers various building performance features. A holistic POE is one that is able to pick the details of what is affecting performance and efficacy of the environment for multiple users with different needs. The combination of qualitative and quantitative data gathered from two types of evaluations; by using interviews and psychological tools and comparing findings to environmental data, this will produce a “rich picture” of the multiple similar and conflicting viewpoints of the primary stakeholders (Jamaludin et al., 2013).

Turpin-Brooks & Vicars, 2006 state that the development of holistic forms of POE should be given further consideration in the property sector. This should address: analysis of organisational/business needs; perceptions of building users; comparative scientific data (e.g. environmental monitoring); psychosocial assessments; economic evaluation of any productivity/environmental changes (including energy audits). A study of a range of POE models resulted in the development of a holistic framework that employs a number of tools and techniques gathered under three categories: recording respondent demographics; employing multiple evaluation techniques; and making recommendations that are cost effective and optimal through consultation with the primary stakeholders. Figure 6 is a pictorial representation of this conceptual framework.

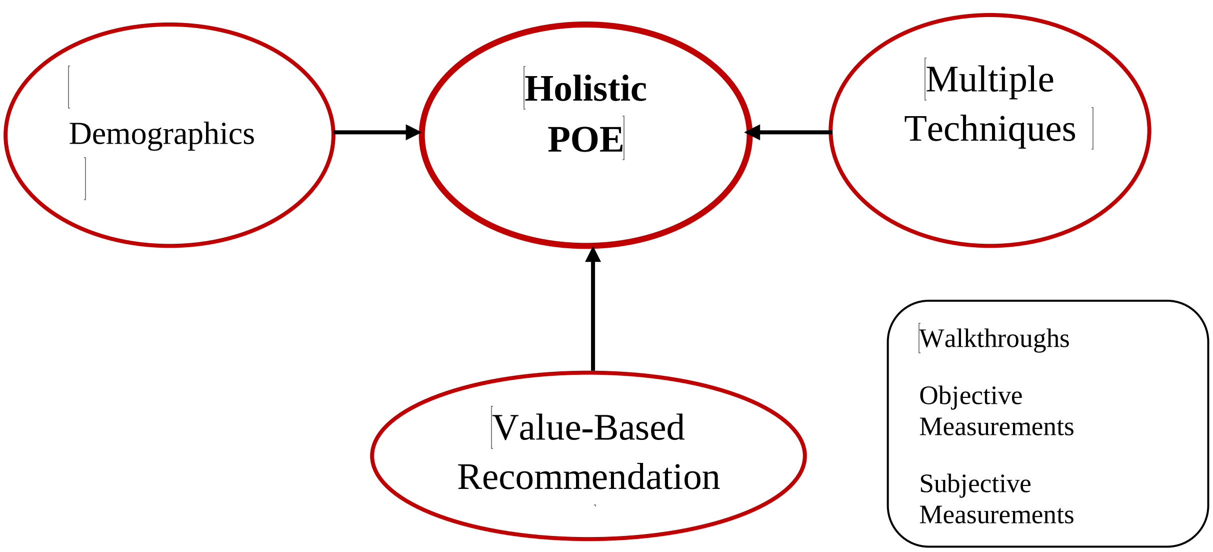


Figure 6. Conceptual model for a holistic POE

3.2 Demographics

Housing satisfaction is not determined only by technical elements of performance, rather the social, behavioural, cultural and other background characteristics of the occupants also plays a huge role. The house is only one link in a chain of factors that determine people's relative satisfaction with their accommodation. This factors are identified by a number of researchers, some of which include age, marital status, the number of children and family size, socio-economic status (income), education, employment and welfare, length of residency, housing physical characteristics, satisfaction with housing physical condition and management, social participation and interaction, past living conditions, as well as residential mobility and future intention to move (Jiboye, 2012). To pick the detail of what is affecting performance and efficacy of the environment for multiple users with different needs, a more qualitative methodology may achieve this holistic solution, by using interviews and psychological tools and comparing such findings to environmental data (Turpin-Brooks & Vicars, 2006).

Though Leaman, 2003 believes that observations about “lifestyle and related management and cultural factors” have negative effects on managers regarding the disclosure of project information and thus should be discouraged in POEs. Leaman et al., 2010 also express further concerns that the variety of lifestyles of buildings’ occupants is a major factor that affects the outcome of a performance evaluation, and makes data difficult to analyse and record. Turpin-Brooks & Vicars, 2006 however exert the need for such data as vital in providing a “complete” picture of satisfaction.

3.3 Multiple Techniques

The distinguishing characteristic of scientific research is the empirical study of hypotheses employing various methods characterised by its own uniqueness. If several of these methods produce similar results, the results thus derived are believed to be of a high level of accuracy (Preiser & Nasar, 2008). Occupant surveys have been carried out on buildings as well energy surveys, however a study that does not combine both methods is regarded as a partial study (Leaman et al., 2010). Jamaludin et al., 2013 pointed out that a combination of qualitative and quantitative data gathered from two types of evaluations presents a holistic picture of the investigated issues. This idea has led researchers to exert more efforts in combining different POE techniques. Turpin-Brooks & Vicars, 2006 emphasise the need for research to test the integrated value of the evaluation of environmental data and human perceptions. Preiser, 2001 also confirms this need to cater for factors that have been omitted in previous POE models like energy performance and sustainability. Though the PROBE methodology was a huge breakthrough in this regard, Fisk 2001 notes that all sustainable development indicators and occupation styles in evaluations are not taken into account in PROBE’s approach.

In recent POE studies of UK housing, research methods have incorporated detailed studies of physical building performance, qualitative evaluation of occupant perception and behaviour and a combination of these approaches. Other relevant literature includes an Energy Saving Trust (EST) protocol for monitoring the energy and carbon performance of new dwellings and a Commission for Architecture and the Built Environment (CABE) survey of residents' attitudes to the design of new housing. In

Canada, a building performance evaluation protocol has been developed by EcoSmart. The protocol has been piloted on six buildings and is publicly available to the design community, including a version that has been adapted for multi-unit residential buildings. However, no details are provided on the costs involved (which are likely to be significant since the protocol draws on the expertise of an acoustics consultant, an indoor air quality consultant, a lighting consultant and a controls and commissioning consultant). Also, the protocol calls for the use of a survey to assess occupant satisfaction, but the survey itself is not included in the scope of the protocol (Taylor et al., 2010).

3.3.1 Walkthroughs

This is a tour around the entire facility meant to identify issues that may require immediate attention by facility managers or issues that require further investigation. In such an inquiry, major problematic zones or elements are identified by recording signs of deterioration or misfit between elements in the facility (Hassanain et al., 2010). Still photography or video recording can be used to identify building attributes that may deserve particular attention. Within a few hours, a walk-through can comprehensively cover a given building (Presier et al., 1988). It can also involve informal discussions with building users to identify conflicts. Its merits and demerits include (AUDE, 2006):

Advantages:

- Few staff resources needed
- Can be done without any end user involvement or inconvenience
- Can provide quantitative data if designed appropriately

- Enables unbiased view

Disadvantages:

- Methodology may demand rigorous application e.g. observations at particular times of the day
- Comparison can be difficult unless observer is given a methodology to apply

3.3.2 Objective Measurements

The assessment of indoor environmental conditions necessarily requires the use of instruments that enable the auditor to detect objectively the variables that define them. All these parameters can be measured with instruments either instantaneously (spot measurement) or continuously (monitoring). Spot measurements of these parameters provide good information but it is useful only at the time that they occurred. Monitoring on the other hand returns an important framework of information: the change of the values over time, which allows us to understand how things really work, and thus allows us to discover problems and propose solutions (Dall, 2013). This type of physical measurements needs a clear strategy to determine measurement points, frequencies and duration of monitoring (AUDE, 2006).

AUDE, 2006 lists the advantages and disadvantages of Physical measurements:

Advantages:

- Quantitative objective data
- Problems can be geographically pinpointed (i.e. where respondent works)

- Problems can be pinpointed in time (e.g. season, time of day)

Disadvantages:

- Expertise needed to take measurements and interpret results
- Appointment of external consultants may be needed
- Hiring of appropriate equipment
- Measurements may need to be taken over a significant period of time, therefore quick, meaningful results may be harder to obtain
- Measuring equipment will be left in place – possibility of disruption and inconvenience

3.3.3 Subjective Measurements

Questionnaire surveys are recognized to be a key component of any building performance evaluation study (Nooraei, et al., 2013). When used appropriately, it communicates the effectiveness of building systems between the facility's users and the facility's management (Jiboye, 2012). Questionnaires can be an industry standard questionnaire or a tailored questionnaire. Industry standard questionnaires are available from consultants or research institutes; they provide the extra benefit of benchmarking a building project against others available in the sector. While a personalized or tailored questionnaire is able to encompass issues specific to the case study. Combining both approaches is however possible, where an industry standard questionnaire that applies to some issues applicable to the case study is used (AUDE, 2006).

In developing personalized questionnaires, an array of performance indicators are developed to address various performance elements contributing to the overall residential satisfaction. Building evaluation models previously adopted simple forms of questionnaires with all indicators considered to be of equal weight and importance. However, it has become more popular with researchers to derive credits and weights based on each indicators relative importance to other indicators. These weights are influenced by ethical or social value judgment based on national, regional, and individual concerns rather than scientific and technical information only (Kim et al., 2005). Questionnaires sometimes also contain an open-ended section so that respondents can provide more qualitative feed-back to cover issues/points not covered in the listed questions. Such qualitative feed-back is analysed separately from the outcomes of the listed questions which is quantitative in nature (Hassanain et al., 2010).

Questionnaires are usually administered as a hard-copy or through the web. Web-based questionnaires present the opportunity of an automatic data analysis by linking the analysis software to the database that is collecting information. Hard copy questionnaires on the other hand allow respondents to complete them as soon as possible to be returned to the surveyor. Worthy of note is the number of response to be received to make the study statistically valid; the clarity of the questions which can be validated through a pilot survey; and the ability to fill in questionnaires in the least time as possible. The following is a list of advantages and disadvantages of questionnaire surveys (AUDE, 2006):

Advantages:

- Generates detailed quantitative data from end users
- Allows performance benchmarking

- Problems can be geographically pinpointed (i.e. where in building respondent works)
- Obtains a broad based opinion
- Anonymity can be given
- Enables comparative surveys to identify trends and responses to remedial action

Disadvantages:

- Requires skilled design
- Requires careful administration to ensure response
- Requires time to complete
- Requires skills to analyse and interpret responses

3.3.4 Focus group meetings

Focus group meetings are used to draw out more qualitative information, usually when key problem areas have been identified through a questionnaire survey and which need deeper understanding. Thus it focuses on a range of selected issues identified by the questionnaire survey (AUDE, 2006). The meetings are organised in the form of brainstorming sessions, with participants selected objectively from a spectrum of dwellers representing different ranks, age groups and ethnicities (Hassanain et al., 2010). In conducting a focus group session, a sample of about 6-8 people should be involved for easy anchoring of the session, while the issues to be discussed should be well defined. The session time should not be longer than necessary and should include breaks if necessary. The following are advantages and disadvantages of focus group meetings (AUDE, 2006):

Advantages:

- Management time needed to prepare is less than for questionnaire survey
- Involves relatively few people
- Enables specific issues to be addressed in detail
- Interactions between attendees enables deeper insights
- Flexibility of coverage, agenda can allow issues to be explored as they are uncovered
- Useful for teasing out broad issues uncovered by questionnaire survey

Disadvantages:

- Expert facilitation needed
- Qualitative data lacks statistical rigour of survey questionnaire
- Bias of those who attend – therefore selection of attendees critical
- No anonymity – people may be reticent to say what they think

3.4 Value-Based Recommendations

Feedback should not be divorced from the evaluation process. The case where evaluators carry out a post occupancy evaluation without fulfilling an effective reporting role is similar to a psychologist allowed to undertake diagnosis and assessment but not actually undertake therapy (Finch, 1999). An effective feed-back provides an opportunity for innovation through lessons learnt and quality control procedures to be embedded in future design and construction practice. This will defeat the perception of academics who consider post occupancy evaluation as not producing new knowledge since its underlying principles and techniques remain largely the same across various studies (Leaman & Bordass 2007). Finch, 1999 clearly states that building performance evaluation should be more than just a capture and analysis of data, it should exceed this simple reporting function by involving solution generation, this will make a significant impact of the design process. In the generation of solutions, a good number of alternative strategies should be developed through continued discussion and analysis with the primary stakeholders while examining the cost and benefit of each strategy, and finally prioritization of recommendations to be implemented as feed-back and feed-forward. This step ensures that the most appropriate actions for the client are initiated (Preiser et al., 1988).

3.5 Holistic POE Framework Methodology

3.5.1 The need

The advancement of technology and the continual and rapid change of the modern and civilized society have resulted in huge demand for well designed, robust, efficient, durable, adaptable, healthy, beautiful and comfortable buildings. In addition to that is the alarming rate of degradation of the environment. Architects, engineers, builders and facility managers are constantly under pressure to make buildings that can perform as expected in today's modern world (Shika, et al., 2014). See figure 18.

3.5.2 Planning Phase

This is where all preliminary work is done to initiate the actual process of evaluation. It also can be called as pre evaluation phase. It involves defining the scope; the level of investigation and the stakeholders involved. The stakeholders are met and relevant background information is acquired, while the time and activities are also agreed upon. A review of literature, historical and other background information is identified and obtained. Resources for conducting the evaluation are organised, and a preliminary schedule, work plan, and budget are established in which project team members' tasks and responsibilities are defined. At the same time, appropriate research methods and analytical techniques are determined, and sources for evaluation criteria are identified (Preiser et al., 1988).

3.5.3 Conducting Phase

The main task is the collection and analysis of data based on the techniques and criteria resulting from the planning phase. Data is collected and analysed based on the performance elements identified from the first phase.

3.5.3.1 Performance Elements

The focus of a POE can be considered in terms of three broad areas: Process, Functional Performance and Technical Performance (AUDE, 2006). A performance indicator "is a sign or marker that points to a condition to be measured, in order to evaluate specific qualities and performances" (Kim et al., 2005). These are usually documented in a facility program, which is a common pre-requisite for the design phases in the building delivery cycle (Preiser et al., 1988). Though performance indicators change according to the evaluation purpose and the case study at hand (Kim et al., 2005), buildings' image and indoor climate are however often given much emphasis at the expense of behavioural and functional aspects of the building performance (Leaman & Bordass 2007).

Technical Elements	**Functional Elements**	**Behavioural Elements**
Thermal Comfort	Layout, Furniture and Spatial Comfort	Privacy and Territoriality
Indoor Air Quality	Support Services	Location
Acoustical Comfort		Appearance
Visual Comfort		
Safety and Security		
Health		
Management and Maintenance		

Figure 7. List of comprehensive performance elements to be investigated

Table 3 and figures 3, 4 and 5 show that none of the previous studies have gathered elements for building performance evaluation in a comprehensive list. Some of the studies have been biased towards the indoor climate (Nooraei et al., 2013 and Inah et al., 2014), while others have been biased towards the functional and behavioural elements of building evaluation (Fatoye & Odusanmi, 2009; Ilesanmi 2010; Jiboye, 2012). This study presents a list of performance elements derived from previous studies and grouped under three traditional categories of building performance evaluation research: Technical, Functional and Behavioural elements. See figure 7. Performance indicators for each of these elements are identified in subsequent detailed discussions.

Assessment tools have been developed with different evaluation criteria based on conditions suitable to the characteristics of the case-studies in various countries for which the tools were designed (Shika et al., 2014). Researchers group performance elements into different categories, however careful study shows that they can be grouped under the three main categories suggested by Preiser et al. 1988. This explained in more detail in the following sections.

A. Technical Performance Elements

They are elements that deal with survival attributes – structure, sanitation, fire safety, and ventilation. Issues of health, safety and security are also dealt with (Preiser et al., 1988). From an environmental perspective, it deals with the issues of Indoor Environmental Quality (IEQ) which affect the comfort, health and productivity of occupants (Choi et al., 2011). These include thermal comfort, indoor air quality, visual comfort and acoustical comfort, which are measured by instrumentation or through administering questionnaires to building users.

A.1 Thermal Comfort

Thermal comfort is one of the main pillars of building performance evaluation (Leifer, 1998; Menzies & Wherrett, 2005; Lai et al., 2009; Meir 2009; Lesbirel, 2012; Lee & Guerin, 2009; ASHRAE 55, 2004; Preiser et al., 1988). A synoptic review of studies in thermal comfort presented in table 4 shows the various terminologies, case-studies and methodologies used by various researchers. Terminologies used include: thermal comfort (Leifer, 1998; Abbaszabeh et al., 2006; Hassanain, 2008; Lai et al., 2009; Frontczak, 2011; Lee and Guerin, 2009; Pfafferott et al., 2004; Kim et al., 2005; Khamidi et al., 2013); and comfort (Gou et al., 2012; Nooraei et al., 2013).

Table 4. Synoptic overview of studies on thermal comfort

Study terminology	Reference	Building type	Methodology
Thermal comfort	Abbaszabeh et al., 2006	Office	Web-based IEQ survey
	Leifer, 1998	Office	Works Canada Office User Satisfaction Survey
	Frontczak, 2011	Office	CBE-UC Berkeley survey + Measure of proximity to windows
	Lee & Guerin, 2009	Office	CBE-UC Berkeley survey + Measure of proximity to windows + Personal thermal controls
	Lai et al., 2009	Residential	Questionnaire + Physical Monitoring
	Pfafferott et al., 2004	Office	Monitoring
	Hassanain et al., 2010	Residential	Questionnaires
	Menzies & Wherrett, 2005	Office	Questionnaires
	Kim et al., 2005	Residential	Computer Software
	Khamidi et al., 2013	Academic complex	Monitoring
Comfort	Gou et al., 2012	Office	BUS questionnaire
	Nooraei et al., 2013	Residential	Questionnaire + Physical Monitoring

The term "thermal comfort" narrows down the more generic term "comfort" to comfort with the thermal environment, and thus it is the preferred terminology in this study. By definition thermal comfort can be viewed from three perspectives: a psychological; a thermo-physiological and one based on the heat balance of the human body. The most popular is the psychological definition provided by (ASHRAE 55, 2004) as "the state of mind that expresses satisfaction with the surrounding thermal environment". Comfort is achieved when heat and mass transfer to and from the body is balanced, skin temperature and sweat rate are within the comfort range (Höppe, 2002).

The major influencers of thermal comfort in an indoor space are the HVAC system or natural ventilation system through windows and other openings; thus, comfort will be determined by the control of both systems (Lesbirel, 2012). More theoretically, the best value of thermal comfort is determined by the Predicted Mean Vote (PMV) according to Fanger's theory; this is obtained when the Percentage of Dissatisfied (PPD) index is equal to 10%, which is when at least 90% of persons are satisfied. Factors that influence thermal comfort include physical factors in the built environment and factors specific to the individual, they are as follows (Lesbirel, 2012; Dall, 2013):

- Temperature
- Relative humidity
- Air velocity
- Temperature of the walls that surround the indoor environment (MRT)
- Clothing of the individual (clo value)
- Activity (metabolic heat)

Thermal comfort can be assessed through walkthroughs, Post Occupancy Evaluation surveys and physical measurements. Figure 8 illustrates the various assessment techniques used to analyse thermal comfort and the variables considered. While walkthroughs are preliminary assessments usually used to identify maintenance issues or behavioural patterns of users, post occupancy surveys and sampling with instruments are more extended forms of assessment.

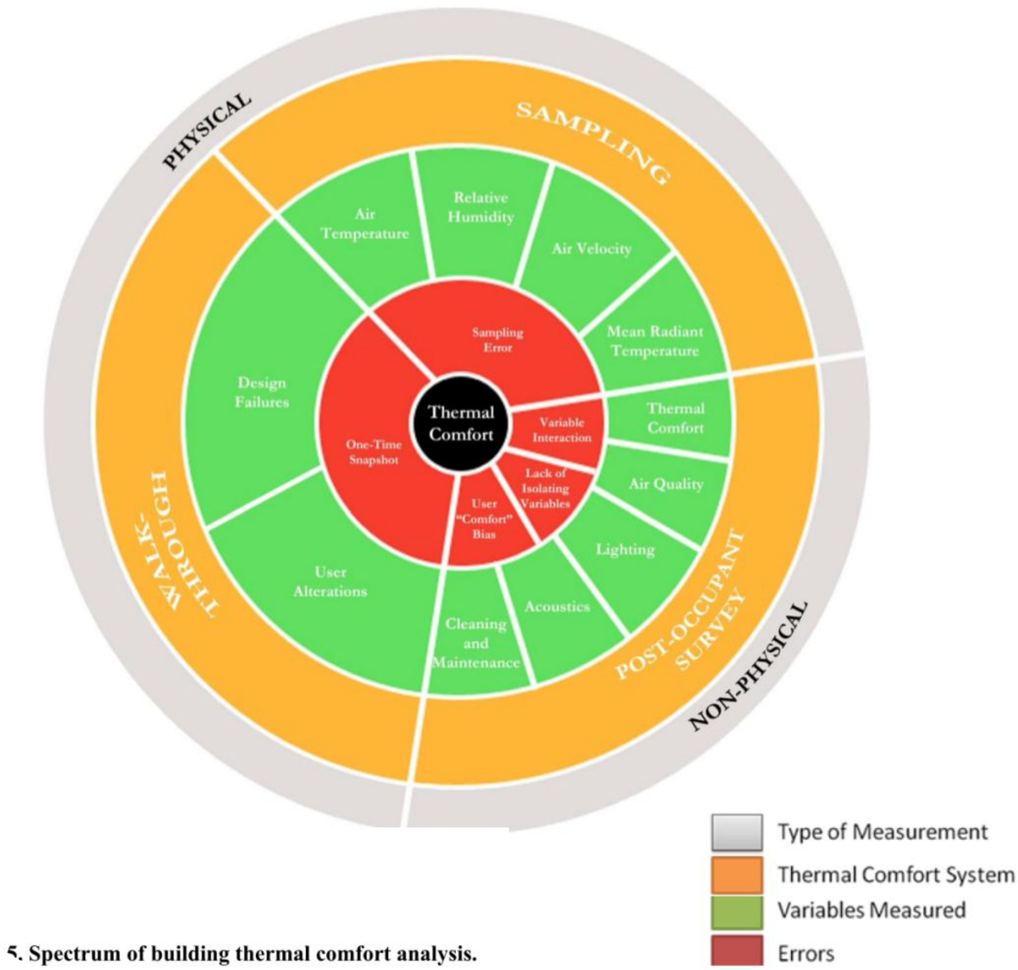


Figure 8. Spectrum of building thermal comfort analysis (As is: Lesbirel, 2012)

Physical Measurement of thermal comfort (i.e. Sampling or Monitoring) is a measure of the four physical factors influencing thermal comfort, which are: temperature; relative humidity; air velocity; and temperature of the walls that surround the indoor environment (or Mean Radiant Temperature, MRT) (Dall, 2013). These could be measured using the solomat metre shown in figure 9. The post occupancy survey is the second means of measuring thermal comfort; it has the extra advantage of taking human perception into consideration. It is based on a Predicted Mean Vote (PMV), according to a 7-point thermal comfort scale provided by (ASHRAE-55) in figure 10. Surveys are designed to follow this scale so that the ASHRAE Human Comfort Index would ideally have the PMV at neutral satisfaction (Lesbirel, 2012).

Performance indicators influencing thermal comfort are as follows:

- The measurement of temperature in summer and winter (Nooraei et al., 2013; Leifer, 1998; Hassanain, 2008; Hassanain et al., 2010; Lee & Guerin, 2009; Gou et al., 2012; Khamidi et al., 2013);
- Overall satisfaction with thermal comfort (Nooraei et al., 2013; Menzies & Wherrett, 2005; Hassanain, 2008; Abbaszadeh, et al., 2006; Lai et al., 2009; Gou et al., 2012; Frontczak, 2011; Ibem 2011);
- Temperature Shift (Leifer, 1998; Gou et al., 2012);
- Humidity (Moezzi & Goins, 2011);
- Air movement (Moezzi & Goins, 2011);
- Incoming sun (Moezzi & Goins, 2011);
- Drafts from windows/vents (Moezzi & Goins, 2011);
- Inaccessible thermostat (Moezzi & Goins, 2011; Lee & Guerin, 2009);
- Control of thermostat by others (Moezzi & Goins, 2011; Lee and Guerin, 2009);
- Control over heating/cooling (Gou et al., 2012; Hassanain et al., 2010)

+3	Hot
+2	Warm
+1	Slightly Warm
0	Neutral
-1	Slightly Cool
-2	Cool
-3	Cold

Figure 9. ASHRAE Human Comfort Index (ASHRAE-55, 2004)

Lesbirel, 2012 pointed out other factors that affect thermal comfort including the design and layout of a building, building orientation, lighting controls and office equipment, the largest influencer being the HVAC system.

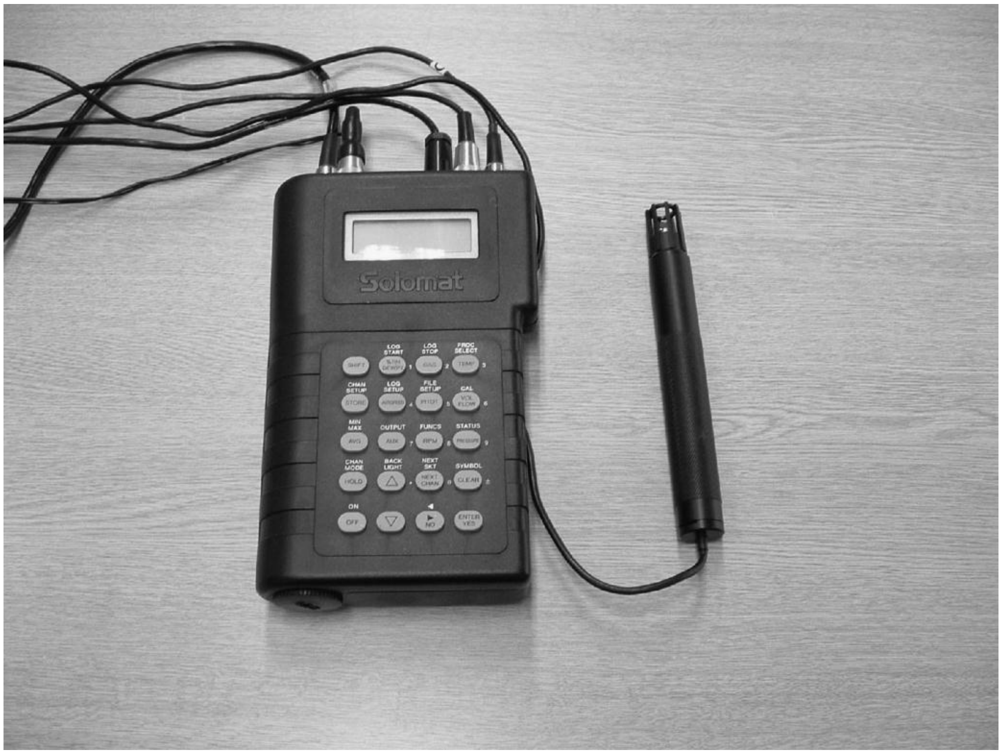


Figure 10. Solomat data logger with temperature and relative humidity probe

A.2 Indoor Air Quality

The need for oxygen and air precedes any other human need. The quality of air impacts on the human health, comfort and productivity; thus it is regarded as a major criterion towards fulfilling occupancy satisfaction in the built environment (Leifer, 1998; Preiser et al., 1988; ASHRAE 62.1, 2004; Lai et al., 2009; Dall, 2013; Anderson et al., 2014). A synoptic review of selected previous studies presented in table 5 show the various terminologies, case-study applications and methodologies used by various researchers. Terminologies used to qualify indoor air quality include: air quality (Leifer, 1998; Abbaszabeh et al., 2006; Frontczak, 2011; Khamidi et al., 2013); indoor air (Kim et al., 2005); indoor air quality (Fatoye & Odusanmi, 2009; Lee & Guerin, 2009; Lai et al., 2009; Hassanain, 2008); and Comfort (Gou et al., 2012); and Air Pollution (Inah et al., 2014). While “air quality” could refer to the quality of air in the indoor and outdoor environment, “indoor air” or better still “indoor air quality” is a more specific term to describe this element. “Comfort" is a generic term, while “Air Pollution” only refers to an aspect of “Indoor Air Quality”.

Dall, 2013 provides a general definition of Indoor Air Quality as the quality of air within a facility or the built environment. Brown, 1997 points out that defining Indoor Air Quality as “the totality of attributes of indoor air that affect a person’s health and well-being necessitates the consideration for thermal requirements and respiratory requirements, prevents unhealthy accumulation of pollutants, and allows for a sense of well-being". This is expressed in more technical terms by Anderson et al., 2014 as “the comfortable range of the temperature, humidity, ventilation and chemical or biological contaminants of the air inside a building”. The major concern is indoor air pollution which can be the cause of asthma, allergies and irritation. Two of the most dreaded implications of poor indoor air quality are: SBS (Sick Building Syndrome) and BRI (Building Related Illnesses); Symptoms of SBS consist of headaches, eye, nose, and throat irritation, coughing, nausea, dizziness, and difficulty in concentration. In 2010, the World Health Organization (WHO) estimated that four million people die every year from causes relating to indoor air pollution which is more than the death toll of acquired immunodeficiency syndrome (AIDS) and malaria combined (Anderson et al., 2014).

Table 5. Synoptic overview of studies on indoor air quality

Study terminology	Reference	Building type	Methodology
Air Quality	Abbaszabeh et al., 2006	Office	Web-based IEQ survey
	Frontczak, 2011	Office	CBE-UC Berkeley survey + Measure of proximity to windows
	Leifer, 1998	Office	Works Canada Office User Satisfaction Survey
	Khamidi et al., 2013	Academic complex	Monitoring
Indoor Air	Kim et al., 2005	Residential	Computer Software
Indoor Air Quality	Fatoye & Odusanmi, 2009	Residential	Personalized questionnaires
	Lai et al., 2009	Residential	Questionnaire + Physical Monitoring
	Lee & Guerin, 2009	Office	CBE-UC Berkeley survey + Measure of proximity to windows + Personal thermal controls
	Hassanain, 2008	Dormitory	Personalised survey
	Hassanain et al., 2010	Residential	Questionnaires
Comfort	Gou et al., 2012	Office	BUS questionnaire
Air Pollution	Inah et al., 2014	Residential	Personalized Questionnaires

Air contaminants include CO_2: environmental tobacco smoke; particles and dust; volatile organic compounds (VOCs); radon (Dall, 2013). See table 6. Indoor air pollutants vary from building to building but include combustion gases from cooking techniques, emissions from paint, cleaning or maintenance supplies, building material odours, and interior decorations (Anderson et al., 2014).

Table 6. Indoor Air Quality Pollutants, sources and health impacts (As is: Anderson et al., 2014)

Pollutant	Sources	Health Impacts
Nitrogen dioxide (NO_2)	Heating and cooking appliances, smoking	Respiratory symptoms and eye irritation
Carbon monoxide (CO)	Heating and cooking appliances, smoking, vehicle emissions	Headaches, chest pain, confusion, rapid breathing, lethal at high levels
Particle matter (PM)	Cooking and aerosols	Reduced lung function and increased risk of heart and respiratory disease
Radon (Rn)	Ground gases, granite building materials	Lung cancer
Volatile organic compounds (VOCs)	Cleaning products, paints, printers, furniture, smoking	Respiratory tract irritation, possible chances of cancer
Ozone (O_3)	Cleaning products, paints, photocopiers, and printers	Respiratory tract irritation, sore throat, tearing, burning, and pain in the eyes
Carbon Dioxide (CO_2)	Smoking and cooking appliances	Headaches, dizziness, and nausea
Formaldehyde (HCHO)	Smoking, paints, furniture, certain wood products, adhesives	Eye and respiratory irritation, lung tissue damage if high concentrations

According to ASHRAE 62.1, 2004, acceptable indoor air quality is achieved by:

- **Controlling the source of the contaminant** which could be outdoor or indoor sources; indoor sources are created by the activities of the building occupants, such as cooking, smoking, photocopying, laser printing, and other processes.

- **Adequate ventilation** is commonly based on measured carbon dioxide (CO_2) levels within the occupied space and is expected to be satisfied if the ventilation results in indoor CO_2 concentrations is less than700 ppm above the outdoor air concentration.

- **Humidity management** which is recommended to be maintained between 30 per cent and 60 per cent. Humidity levels less than 30 per cent cause some people respiratory discomfort while humidity levels over 70 per cent near surfaces for extended periods of time promote the growth of some forms of mould and fungi.

- **Adequate filtration** to remove or control contaminants to acceptable limits. Contaminants exist as discrete grains or particles including: pollen, microorganisms, skin flakes, dust, fumes, and smoke; and their particle sizes range from 0.01 to more than 100 microns. Particles of 10 microns or less generally pose the greatest health hazard because they are small enough to penetrate the natural defences of the body's respiratory system. See table 6 for a list of Indoor air pollutants. Appendix B of ASHRAE 62.1, 2004 provides acceptable indoor concentration levels for some common contaminants. Burnett, 2005 also provides a list of the Hong Kong IAQ certification scheme acceptable standards presented in table 7.

Table 7. Criteria for Hong Kong IAQ Certification Scheme

Parameter	Units	'Excellent'	'Good'
Temperature (T)	Celsius (°C)	20 – 25.5	< 25.5
Relative Humidity (RH)	%	40 – 70	< 70
Air Movement	meters per second (m/s)	< 0.2	< 0.3
Carbon Dioxide (CO_2)	parts per million (ppm)	< 800	< 1000
Carbon Monoxide (CO)	ppm	< 1.7	< 8.7
	μg/m^3	< 2,000	< 10,000
Respirable Suspended Particulates (RSP) (PM_{10})	microgram per cubic meter (μg/m^3)	< 20	< 180
Nitrogen Dioxide (NO_2)	μg/m^3	< 40	< 150
	parts per billion (ppb)	< 21	< 80
Ozone (O_3)	μg/m^3	< 50	< 120
	ppb	< 25	< 61
Formaldehyde (HCHO)	μg/m^3	< 30	< 100
	ppb	< 24	< 81
Total Volatile Organic Compounds (TVOC)	μg/m^3	< 200	< 600
	ppb	< 87	< 261
Radon (Rn)	becquerel per cubic meter (Bq/m^3)	< 150	< 200
Airborne Bacteria Count (ABC)	colony forming units per cubic meter (CFU/m^3)	< 500	< 1,000

Non dispersive infra-red (NDIR) sensors as shown in figure 11 can be used to measure carbon dioxide (CO_2) concentrations, air temperature and relative humidity (Burnett, 2005). Subjectively indoor air quality is measure using the post occupancy survey, however this is only used to detect odours or irritants perceivable by human occupants or visitors to a space ASHRAE 62.1, 2004 states that "the air can be considered acceptably free of annoying contaminants if 80% of a panel of at least 20 untrained observers deems the air to be not objectionable under representative conditions of use and occupancy. An observer should enter the space in the manner of a normal visitor and should render a judgment of acceptability within 15 seconds. Each observer should make the evaluation independently of other observers and without influence from a panel leader".

Subjective performance indicators of Indoor Air Quality identified by previous researchers include:

- Overall satisfaction with indoor air quality (Hassanain, 2008; Lai et al., 2009; Lee & Guerin, 2009; Anderson et al., 2014; Fatoye & Odusami 2009; Gou et al., 2012);
- Temperature (Anderson et al., 2014);
- Humidity (Anderson et al., 2014; Gou et al., 2012);
- Odour/Air pollution (Fatoye & Odusami 2009; Anderson et al., 2014; Gou et al. 2012; Khamidi et al., 2013; Inah et al., 2014);
- Quality/freshness of air (Leifer, 1998; Hassanain, 2008; Hassanain et al., 2010; Gou et al., 2012; Khamidi et al., 2013; Ibem, 2011);
- Control of natural ventilation (Hassanain, 2008; Gou et al., 2012);
- Control of mechanical ventilation (Hassanain, 2008; Gou et al., 2012);
- Ventilation comfort (Liu, 1999; Nooraei et al., 2013; Leifer, 1998; Inah et al., 2014);
- Air flow (Leifer, 1998; Anderson et al., 2014; Gou et al., 2012; Khamidi et al., 2013);

Figure 11. Supco IAQ50 Wall Mounted Indoor Air Quality Monitor

A.3 Visual Comfort

A healthy visual environment involves the optimal design of lighting to support the activities of building occupants; hence visual comfort has been identified through research as a significant factor in the performance of buildings as regards Indoor Environmental Quality (Preiser et al., 1988; Abbaszabeh et al., 2006; Frontczak, 2011; Lee & Guerin, 2009; Nooraei et al., 2013; Hassanain, 2008; Menzies & Wherrett, 2005). Table 8 is a synoptic review of studies on visual comfort; most of the studies identified prefer to use the term lighting (Abbaszabeh et al., 2006; Frontczak, 2011; Lee & Guerin, 2009; Nooraei et al., 2013; Leifer, 1998; Gou et al., 2012; Khamidi et al., 2013), in contrast to Visual Comfort adopted by (Preiser et al., 1988; Kim et al., 2005; Lai et al., 2009; Hassanain, 2008), other studies may simply spell out indicators like Day lighting, use of electric lighting, glare problems (Menzies & Wherrett, 2005). For a Post Occupancy Evaluations that emphasises Occupants' satisfaction, comfort and well-being, the term "Visual Comfort" is considered more appropriate. Terminologies like "Lighting" can refer to the performance of this element, but does not highlight the comfort and well-being of the occupants.

The Illuminating Society of North America (IESNA) defines Visual comfort as "an essential human need that can affect task performance, health and safety, and mood and atmosphere". Visual comfort is a subset of visibility which is interrelated with task performance; social communication; health safety and wellbeing (IESNA, 2000; Hassanain, 2008). See figure 12. Visual comfort involves two major aspects: the adequacy of lightning to provide visibility; and the elimination of disturbing effects like discomfort glare. Thus it can be defined as "human satisfaction with visibility provided by lightning sources and the control of disturbing effects like discomfort glare to ensure better productivity and overall wellbeing" (Dall, 2013).

Table 8. Synoptic overview of studies on visual comfort

Study terminology	Reference	Building type	Methodology
Lighting	Abbaszabeh et al., 2006	Office	Web-based IEQ survey
	Frontczak, 2011	Office	CBE-UC Berkeley survey + Measure of proximity to windows
	Moezzi & Goins, 2011	Office	CBE-UC Berkeley survey
	Lee & Guerin, 2009	Office	CBE-UC Berkeley survey + Measure of proximity to windows + Personal thermal controls
	Nooraei et al., 2013	Residential	Questionnaire + Physical Monitoring
	Leifer, 1998	Office	Works Canada Office User Satisfaction Survey
	Gou et al., 2012	Office	BUS questionnaire
	Khamidi et al., 2013	Academic Village	Monitoring
Visual comfort	Kim et al., 2005	Residential	Computer Software
	Lai et al., 2009	Residential	Questionnaire + Physical Monitoring
	Hassanain, 2008	Dormitory	Questionnaires
	Hassanain et al., 2010	Residential	Questionnaires
Day lighting, use of electric lighting, glare problems	Menzies & Wherrett, 2005	Office	Questionnaires

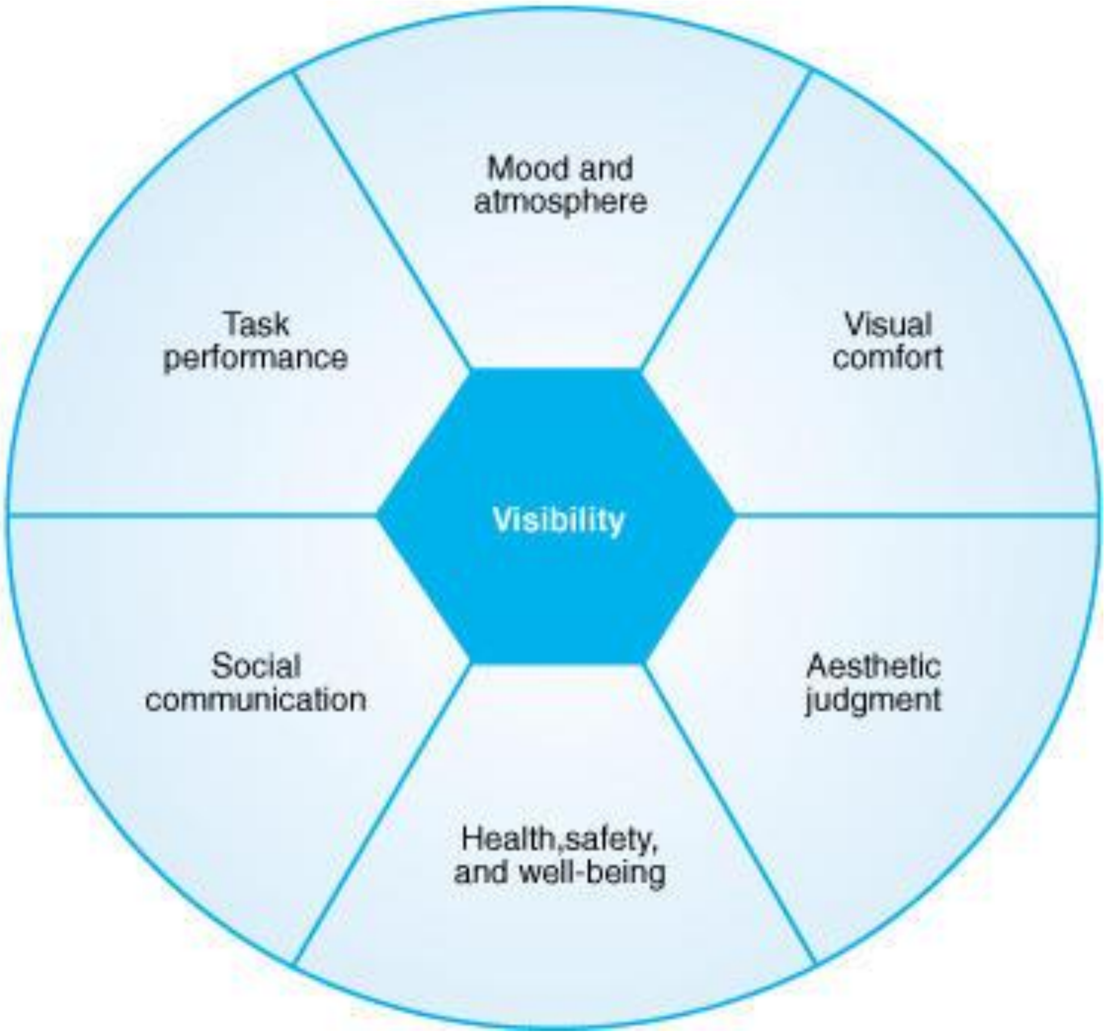


Figure 12. Human needs served by lighting (As is: IESNA, 2000)

Lighting adequacy vary with specific human needs and tasks to be carried out. The lighting requirement for an aged occupant varies with a younger occupant to achieve the same speed and accuracy in performing tasks. The major factor in measuring lighting adequacy is the luminance – measure of the amount of light leaving a surface; and illuminance - a measure of the amount of light incident on a surface (Williams, 1999). This can be measured physically with the aid of devices shown in table 9. Lighting requirements are estimated to be 50 lux for corridors and walkways while studying an engineering drawing may require 750 lux (Dall, 2013). The primary authority for lighting requirements is the Illuminating Society of North America (IESNA) (Richmann). IESNA has published illuminance recommendations in tables covering both generic tasks (reading, writing etc.), and 100's of very specific tasks and activities (such as drafting, parking, milking cows, blowing glass and baking bread). See Table 10 (Williams, 1999).

Table 9. Feature of digital light meters (As is: Hwang and Kim, 2011)

Models	**Topcon IM-5 (illuminance)**	**Lutron YK-2005LX (illuminance)**	**Minolta CA-2000A (luminance)**
Sensor	Silicon photo diode	Silicon photo diode	CCD image sensor
Range	0.01–199,900	0.1–100,000 lx	0.1–100,000 cdm^{-2}
Accuracy	±1 digit	±2 digits	3%
Sampling	Real time	2s–9h	Real time
Image			

Subjectively, visual comfort is measured using a questionnaire survey, which takes into consideration occupants' satisfaction with the quantity and quality of lighting, glare, control of shadows, luminance, and adequate illuminance. The survey is designed based on the 7-point likert scale similar to ASHRAE's Human comfort index.

Table 10. IESNA illuminance categories and values - for generic indoor activities (As is: Williams, 1999)

Activity	Category	Lux
Public spaces with dark surroundings	A	20 – 30 – 50
Simple orientation for short temporary visits	B	50 – 75 – 100
Working spaces where visual tasks are only occasionally performed	C	100 - 150 – 200
Performance of visual tasks of high contrast or large size	D	200 – 300 – 500
Performance of visual tasks of medium contrast or small size	E	500 – 750 – 1000
Performance of visual tasks of low contrast or very small size	F	1000 – 1500 – 2000
Performance of visual tasks of low contrast or very small size over a prolonged period	G	2000 – 3000 – 5000
Performance of very prolonged and exacting visual tasks	H	5000 – 7500 – 10000
Performance of very special visual tasks of extremely low contrast	I	10000 – 15000 – 20000
A – C for illuminances over a large area (i.e. lobby space) D – F for localized tasks G – I for extremely difficult visual tasks		

Subjective performance indicators of visual comfort identified by previous researchers include:

- Overall satisfaction with visual comfort (Lee & Guerin, 2009; Hassanain, 2008; Frontczak, 2011; Gou et al., 2012; Hwang & Kim, 2011);
- Daylight (natural lighting) (Liu, 1999; Menzies & Wherrett, 2005;

Leifer, 1998; Hassanain, 2008; Hassanain et al., 2010; Nooraei et al., 2013; Gou et al., 2012; Khamidi et al., 2013; Moezzi & Goins, 2010; Ibem, 2011);

- Illumination level/How bright are the lights (artificial lighting) (Leifer, 1998; Hassanain, 2008; Hassanain et al., 2010; Lai et al., 2009; Lee & Guerin, 2009; Frontczak, 2011; Gou et al., 2012; Moezzi & Goins, 2010; Hwang & Kim, 2011);
- Use of Electric lighting (control) (Leifer, 1998; Menzies & Wherrett, 2005; Hassanain, 2008; Moezzi & Goins, 2010);
- Glare problems (Leifer, 1998; Menzies & Wherrett, 2005; Khamidi et al., 2013; Moezzi & Goins, 2010; Hwang & Kim, 2011);
- Adequacy of lighting levels in the corridors of the building (Hassanain, 2008);
- Effectiveness of shutter (Control of daylight) (Khamidi et al., 2013; Moezzi & Goins, 2010);

A.4 Acoustic Comfort

Acoustic comfort is one of the Indoor Environmental Quality components that influence occupancy satisfaction, health and wellbeing in the built environment. Noise-induced hearing loss (NIHL) is one of the major concerns of occupational and general health (Al Shimemeri et al., 2011). A number of studies have investigated this element (Abbaszabeh et al., 2006; Frontczak, 2011; Moezzi & Goins, 2011; Lee & Guerin, 2009; Kim et al., 2005; Menzies & Wherrett, 2005; Fatoye & Odusanmi, 2009). This is however perceived differently by various researchers, a synoptic review of studies presented in table 11 show the various terminologies, case-studies and methodologies used by various researchers. Terminologies used to qualify acoustic comfort include:

Acoustics (Abbaszabeh et al., 2006; Frontczak, 2011; Moezzi & Goins, 2011); Acoustic Quality (Lee & Guerin, 2009); Acoustic Comfort (Kim et al., 2005; Menzies & Wherrett, 2005; Hassanain, 2008); Noise (Gou et al. 2012; Khamidi et al., 2013) Noise level (Nooraei et al., 2013); Aural Comfort (Lai et al., 2009); Noise Control (Leifer, 1998); Noise Pollution (Fatoye & Odusanmi, 2009). The most common themes however are Acoustics and Acoustic comfort, the latter is more suitable in describing the element for a post-occupancy evaluation aimed at assessing the comfort, wellbeing and satisfaction of building occupants.

Table 11. Synoptic overview of studies on acoustic comfort

Study terminology	Reference	Building type	Methodology
Acoustics	Abbaszabeh et al., 2006	Office	Web-based IEQ survey
	Frontczak, 2011	Office	CBE-UC Berkeley survey + Measure of proximity to windows
	Moezzi & Goins, 2011	Office	CBE-UC Berkeley survey
Acoustic Quality	Lee & Guerin, 2009	Office	CBE-UC Berkeley survey + Measure of proximity to windows + Personal thermal controls
Acoustic Comfort	Kim et al., 2005	Residential	Computer Software
	Menzies & Wherrett, 2005	Office	Questionnaires
	Hassanain, 2008	Dormitory	Questionnaires
Noise	Gou et al., 2012	Office	BUS questionnaire
	Khamidi et al., 2013	Academic Village	Monitoring
Noise level	Nooraei et al., 2013	Residential	Questionnaire + Physical Monitoring
Aural Comfort	Lai et al., 2009	Residential	Questionnaire + Physical Monitoring
Noise Control	Leifer, 1998	Office	Works Canada Office User Satisfaction Survey

Noise Pollution	Inah et al., 2014	Residential	Personalized Survey
	Fatoye & Odunsanmi, 2009	Residential	Personalized questionnaires

In housing facilities, noise mainly originate from traffic, aircraft, construction sites, and activities in adjacent buildings or spaces. Noise generated from building services is relatively minor and negligible. However, very high noise levels, prolonged exposure to noise, and noise during sleep may cause irritation, mental stress, and hearing loss. Primary to providing quiet environment are walls, floors, windows, and doors providing adequate reduction of sound from adjacent activities (Hassanain, 2008). Acoustic comfort can be defined as providing acoustic conditions in a building that facilitate clear communication of speech between the users of the building (Ben Lasod, 2013). It is achieved when the workplace provides appropriate acoustical support for interaction, confidentiality, and concentrative work (GSA, 2011). A detailed and more relevant definition to the residential context is provided by (Preiser et al., 1988): "acoustic comfort covers the ambient level of sound, the transmission of sound between areas and rooms, reverberation, and specific areas such as machine noise and auditorium acoustics".

Noise can be measured subjectively through human perception. Focus is usually given to places of work, learning and worship centres (Al Shimemeri et al., 2011). The human ear however is not sensitive to all sounds. Objectively, sound level meters (SLM) meters are used to determine frequency weightings which give readings equivalent to the human perception of sound. See figure 13. A number of measures exists for acoustic comfort evaluation including: the equivalent sound pressure level (SPL); the noise criterion (NC) curves; the balanced noise criterion (BNC); the noise rating (NR); the preferred noise criterion (PNC); the room criterion (RC); and the loudness level. Previous research indicates that the A-weighting equivalent sound pressure level (SPL) is the most commonly used and the best and most convenient measure due to its closeness to the human perception of sound (Lai et al., 2009). Continuous exposure to A-weighted sound levels over 85 dB can cause permanent hearing loss (CertainTeed). Table 12 is a list of recommended ranges for background noise levels in interior spaces, the noise criterion provided in table can subsequently be converted to its dBA levels.

Table 12. Category Classification and Suggested Noise Criterion Range for Intruding Steady-State Noise as Heard in Various Spaces (As is: US Department of Defense, 2003)

Category	Area (and Acoustic Requirements)	Noise Criterion
1	Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels, etc. **(for sleeping, resting, relaxing).**	NC-20 TO NC-30
2	Auditoriums, theaters, large meeting rooms, large conference rooms, radio studios, churches, chapels, etc. **(for very good listening conditions).**	NC-15 TO NC-30
3	Private offices, small conference rooms, classrooms, libraries, etc. **(for good listening conditions).**	NC-30 TO NC-35
4	Large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc. **(for fair listening conditions).**	NC-35 TO NC-40
5	Lobbies, drafting and engineering rooms, laboratory work spaces, maintenance shops such as for electrical equipment etc**. (for moderately fair listening conditions).**	NC-40 TO NC-50
6	Kitchens, laundries, shops, garages, machinery spaces, power plant control rooms, etc. **(for minimum acceptable speech communication, no risk of hearing damage).**	NC-45 TO NC-65

The subjective evaluation of acoustic comfort is identified through literature to include indicators such as:

- Overall satisfaction with noise (Liu, 1999; Fatoye & Odunsanmi, 2009; Gou et al., 2012; Lee & Guerin, 2009; Menzies & Wherrett, 2005; Hassanain, 2008; Lai et al., 2009)
- Noise distractions (Leifer, 1998)
- Background noise level (Leifer, 1998; Khamidi et al., 2013)
- Specific noises (Leifer, 1998)
- Noise from air system/HVAC system (Leifer, 1998; Hassanain, 2008; Moezzi & Goins, 2011)
- Noise from lightning (Leifer, 1998; Hassanain, 2008; Moezzi & Goins, 2011)
- Noise from outside the building (Leifer, 1998; Gou et al. 2012; Khamidi et al., 2013; Hassanain, 2008; Moezzi & Goins, 2011)
- Noise from people between rooms/Sound Privacy (Lee & Guerin, 2009; Gou et al., 2012; Hassanain, 2008; Moezzi & Goins, 2011)
- Control over noise (Gou et al., 2012; Ibem, 2011)

Figure 13. Sound Pressure Level (SPL) meter

A.5 Safety and Security

Fire safety is one of the earliest elements to be evaluated systematically, probably due to enormous concerns for life and property (Preiser et al., 1988). Security and Fire safety is usually treated in studies of risk assessment and evacuation studies. This is probably due to the fact that researchers prefer to evaluate security and fire safety objectively. Objective evaluation of fire safety is carried out with the use of Checklists tailored according to code requirements like the International Building Code (IBC) 2012.

Nevertheless, Security and Safety is of major concern to building owners, designers, constructors and managers. Table 13 is a synoptic review of few studies that evaluate security and fire safety subjectively with different terminologies and case study applications; such as Fire safety (Hassanain, 2008); Safety and Security (Liu, 1999; Khalil & Nawawi, 2008; Hassanain et al., 2010); and Security (Fatoye & Odusami, 2009). Safety and Security best describes the issues related to this element including security and safety systems implemented within and around the building's surroundings.

Safety and security of communities is defined as "the protection and securing of residents and their property, prevention of anything that may threaten them, investigation of crimes and community participation in efforts to address causes of crime" (http://www.etu.org.za/toolbox/docs/government/safety.html). It is also defined as “the control of recognised hazards to achieve an acceptable level of risk” (Ben Lasod, 2013). Relevant criteria include the fire resistance of the major structural elements of a building, fire extinguishment and containment, flame spread, smoke generation, the toxicity of burning materials, and the ease of egress in case of a fire (Preiser et al., 1988).

Table 13. Synoptic overview of studies on security and safety

Study terminology	Reference	Building type	Methodology
Fire Safety	Hassanain, 2008	Dormitory	Personalized questionnaires
Safety and Security	Khalil & Nawawi, 2008	Government and Public Buildings	Personalized questionnaires
	Liu, 1999	Residential	Questionnaires
	Hassanain et al., 2010	Residential	Questionnaires

Security	Fatoye & Odunsanmi, 2009	Residential	Personalized questionnaires

Through a review of literature of the performance indicators used to subjectively evaluate safety and security, the following indicators were identified:

- Overall satisfaction with safety and security (Khalil & Nawawi, 2008)
- Ease to identify emergency exits to occupants and visitors/ Emergency/Escape route (Hassanain, 2008; Fatoye & Odusami, 2009)
- Anti-crime measure (Ukoha & Beamish, 1997; Liu, 1999)
- Ease of exiting the building in cases of fire emergencies (Liu, 1999; Hassanain, 2008)
- Ease to identify and reach fire alarm systems (Hassanain, 2008)
- Quality and perception of fire safety systems in the building (Liu, 1999; Hassanain, 2008; Ibem 2011)
- Security system of your house (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014)
- Security level of your neighbourhood (Liu, 1999; Fatoye & Odusami, 2009)
- Level of safety measures in children playground areas (Hassanain et al., 2010)
- Level of safety measures in outdoor areas (Hassanain et al., 2010)
- Level of safety measures in streets and walkways (Hassanain et al., 2010)
- Availability of emergency preparedness measures in outdoor planning (Hassanain et al., 2010)
- Enforcement of maximum speed limit rules (Hassanain et al., 2010)
- Quality of provided speed pumps (Hassanain et al., 2010)
- Quality of landscape design in facilitating safe driving (Hassanain et al., 2010)
- Protection against insects and dangerous animals (Ibem, 2011)

A.6 Health

The goal of building design and construction is to provide healthy environments to sustain the activities of its occupants. This is a direct implication of the Indoor Environmental quality since occupants spend about 90% of their time indoors. Two of the most dreaded implications of poor indoor air quality are: SBS (Sick Building Syndrome) and BRI (Building Related Illnesses). Symptoms of SBS consist of headaches, eye, nose, and throat irritation, coughing, nausea, dizziness, and difficulty in concentration (Anderson et al., 2014). Health is the overall well-being of building occupants in response to the indoor environmental quality, usually an issue for concern in office buildings. Few researchers single out health as a performance element to be investigated subjectively (Gou et al., 2012; Nooraei et al., 2013; Leifer, 1998; Liu, 1999), see table 14. Performance indicators to investigate health in previous studies are listed as follows:

- Apartment's effect on health (Gou et al., 2012; Nooraei et al., 2013)
- Condition of health (Skin/eyes/nose/throat/chest) (Leifer, 1998)
- Do you experience the following (headaches/lethargy/tiredness) (Leifer, 1998)

Table 14. Synoptic overview of studies on health

Study terminology	Reference	Building type	Methodology
Health	Gou et al., 2012	Office	BUS questionnaire
	Nooraei et al., 2013	Residential	Questionnaire + Physical Monitoring
	Liu, 1999	Residential	Questionnaire

A.7 Management and Maintenance

Maintenance management is one of the most important issues in buildings (Nor 'Aini et al., 2013). High quality maintenance is one of the major drivers of tenants' satisfaction. Maintenance is defined by a number of professionals including: (van Mossel & Jansen, 2010) as "work needed to keep a dwelling at or to restore a dwelling to an acceptable standard, and also includes minor improvements"; (Lai & Pang 2010) as "activities that can prevent building decay, diminish breakdowns, and eliminate safety hazards". The philosophy of maintenance is to keep a building in a state as close as possible to its original state, similar to the definition given by van Mossel & Jansen, 2010.

Table 15. Synoptic overview of studies on management and maintenance

Study terminology	Reference	Building type	Methodology
Cleanliness and Maintenance	Gou et al., 2012	Office	CBE occupant satisfaction survey
Management and Maintenance	Nooraei et al., 2013	Residential	Questionnaire + Physical Monitoring
	Liu, 1999	Residential	Questionnaire
Housing/Building Maintenance	Nor 'Aini et al., 2013	Residential	Questionnaire
	Van Mossel & Jansen, 2010	Residential	Questionnaire
	Inah et al., 2014	Residential	Questionnaire
Maintenance Quality	Ilesanmi, 2009	Residential	Questionnaire
Public Housing Management	Ukoha & Beamish, 1997	Residential	Questionnaire

Table 15 is a synoptic review of selected previous studies that evaluate building maintenance subjectively with different terminologies and case study applications; including Management and Maintenance (Liu, 1999; Nooraei et al., 2013); Cleanliness and Maintenance (Gou et al., 2012); and Housing/Building Maintenance (Nor 'Aini et al., 2013; van Mossel & Jansen, 2010; Inah et al., 2014); Maintenance Quality (Ilesanmi, 2009); Public Housing Management (Ukoha & Beamish, 1997). Management and Maintenance best describes the element since occupant satisfaction is also influenced by the effectiveness and quality delivery of the maintenance team.

A number of research have focused on the performance of maintenance services objectively and subjectively. Traditionally, maintenance performance is measured based on financial considerations. This has been critiqued by researchers who opine that performance measurement should be objectively based on the building physical characteristics, services and environment, with the use of codes, standards or bye-laws. The more popular approach is the subjective approach which obtains occupants' perceptions (Nor 'Aini et al., 2013). Performance indicators that define tenants' satisfaction are not well defined (van Mossel & Jansen, 2010), however through a review of previous studies the following performance indicators are identified:

- Quality management and maintenance of facilities in the housing estate (Fatoye & Odusami, 2009; Nor 'Aini et al., 2013; Liu, 1999; Ibem, 2011; Gou et al., 2012; Nooraei et al., 2013)
- Maintenance of building components (Exterior paintwork; Hinges and locks of windows and external doors; Kitchens; Drains; Toilets; Bathrooms; Roofs and gutters; Cleaning of shared areas (multi-family dwelling only); Balconies (multi-

family dwelling only); Entrance hall, gallery, corridors and/or stairs (multifamily dwelling only)) (van Mossel & Jansen, 2010)

- Maintenance of installations (Heating and water systems; Ventilation systems; Lifts (multi-family dwelling only); Lighting in shared areas (multi-family dwelling only)) (van Mossel & Jansen, 2010)
- Maintenance of surrounding grounds (Paving around the building; Communal greenery (multi-family dwelling only)) (van Mossel & Jansen 2010; Gou et al., 2012)
- Easiness (and cost) of maintenance of house (Fatoye & Odusami, 2009; Inah et al., 2014)
- Low-cost maintenance features in your house (Fatoye & Odusami, 2009)
- Level of Deterioration in building (Fatoye & Odusami, 2009)
- Frequency of house maintenance (Inah et al., 2014)
- Speed and efficiency of maintenance services for indoor facilities (Liu, 1999; Hassanain et al., 2010; Nor 'Aini et al., 2013; Nooraei et al., 2013)
- Treatment of residents (Ukoha & Beamish, 1997)
- Handling of residents' complaints (Ukoha & Beamish, 1997)
- Management response to necessary repairs (Ukoha & Beamish, 1997)
- Management team has resources to do the job (Nor 'Aini et al., 2013)
- Maintenance team is easy to contact (Nor 'Aini et al., 2013)
- Maintenance team keep residents informed (Nor 'Aini et al., 2013)
- Maintenance team provides good value for money (Nor 'Aini et al., 2013)

B. Functional Performance Elements

This deals with the functionality and efficiency level of the features in the housing. Functional elements include accessibility, spatial capacity for activities, and adequacy of necessary facilities. Other elements include utilities, telecommunications, responsiveness to change over time, and efficiency of communication and circulation.

The functional elements of a building directly support activities within it, and they must be responsive to the specific needs of the occupants (Preiser et al., 1988).

B.1 Layout, Furniture and Spatial Comfort

Spatial comfort is a fundamental part of a building performance and occupancy comfort (Gou et al., 2012; Frontczak, 2011; Lee & Guerin, 2009; Hassanain, 2008; Leifer, 1998). According to Hartkopf et al., 1986, spatial comfort entails the layout of space, furniture, and storage and the convenient circulation and accessibility to various usable spaces within a building. Space is a basic concern in both architecture and the behavioural sciences. Spatial attributes, the sequence, location, relationships, shape, size, and detail of spaces have been shown to affect occupant behaviour (Preiser et al., 1988). The interior layout of the building should be efficient in terms of the arrangement of rooms in each level in the building, the width of the corridors for circulation inside the building, and the location and number of stairs in the building (Hassanain, 2008). Storage facilities are also a critical aspect of POEs since they are always inadequate if provided. Although the quantity of storage is a major criterion, the type, size, location, and distribution of storage are also important factors (Preiser et al., 1988).

A synoptic review of previous studies presented in table 16 shows the various terminologies, case-studies and methodologies used by various researchers. Terminologies used include: Space (Gou et al., 2012; Frontczak, 2011; Lee & Guerin, 2009); Room layout and furniture quality (Hassanain, 2008); Storage (Gou et al., 2012); and Spatial comfort (Leifer, 1998). This shows that researchers are not consistent in describing this element, and it is more comprehensive to rather qualify it as layout, furniture and spatial comfort.

Table 16. Synoptic overview of studies on Layout, Furniture and Spatial Comfort

Study terminology	Reference	Building type	Methodology
Space	Gou et al., 2012	Office	BUS questionnaire
	Frontczak, 2011	Office	CBE-UC Berkeley survey + Measure of proximity to windows
	Lee & Guerin, 2009	Office	CBE-UC Berkeley survey + Measure of proximity to windows + Personal thermal controls
Room layout and furniture quality	Hassanain, 2008	Dormitory	Personalised survey
Spatial configuration, housing unit layout, finish systems and furniture	Hassanain et al., 2010	Residential	Questionnaires
Storage	Gou et al., 2012	Office	BUS questionnaire
Spatial Comfort	Leifer, 1998	Office	Works Canada Office User Satisfaction Survey

Performance indicators can be assessed through a walkthrough inspection to assess the quality, arrangement and adequacy of furniture, or through questionnaire surveys. A list of performance indicators based on reviewed literature is as follows:

- Overall satisfaction with space (Liu, 1999; Gou et al., 2012)
- Type of house (Liu, 1999; Ibem, 2011)
- Furniture arrangement (Hassanain, 2008; Leifer, 1998)
- Quality of furniture (Hassanain, 2008; Hassanain et al., 2010; Frontczak, 2011; Lee & Guerin, 2009)

- Amount of space/Size of the rooms (Ukoha & Beamish, 1997; Hassanain, 2008; Hassanain et al., 2010; Fatoye & Odusami, 2009; Leifer, 1998; Frontczak, 2011; Ibem, 2011; Lee & Guerin, 2009; Inah et al., 2014)
- Personal storage/Capacity of wardrobe (Ukoha & Beamish, 1997; Hassanain, 2008; Leifer, 1998; Fatoye & Odusami, 2009; Gou et al., 2012; Inah et al., 2014)
- Location of rooms in your house (Ukoha & Beamish, 1997; Hassanain, 2008; Fatoye & Odusami, 2009; Inah et al., 2014)
- No of rooms in your house (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009; Inah et al., 2014; Hassanain et al., 2010; Ibem, 2011)
- Room performance/Layout of the rooms (Liu, 1999; Fatoye & Odusami, 2009; Inah et al., 2014)
- Vertical/Horizontal circulation within building (Liu, 1999)
- Scale and proportion of the floor plan (Fatoye & Odusami, 2009)
- Ceiling height (Liu, 1999; Fatoye & Odusami, 2009; Inah et al., 2014)
- Plot size (Fatoye & Odusami, 2009)
- Adequacy of circulation routes around the building (Hassanain, 2008; Hassanain et al., 2010)
- Individual space for each member of your household (Fatoye & Odusami, 2009)
- Space for landscaping (Fatoye & Odusami, 2009)
- Functionality in design (Inah et al., 2014)
- Suitability of the location of bathrooms relative to guest reception area (Hassanain et al., 2010)
- Quality of carpentry work for (doors and windows, kitchen cabinets, bathroom cabinets, closet/wardrobe) (Hassanain et al., 2010)

B.2 Housing Support Services

Housing services and infrastructure is an integral part of the housing environment and a major influence on residential satisfaction as well as quality of life of residents (Ibem, 2011). Adequacy and quality of housing services is usually ignored in building performance evaluation research, most of the focus is given to the Indoor Environmental Quality. Table 17 presents a review of previous studies carried out, there is no consistent terminology for qualifying this element, support services has been adopted by (Hassanain, 2008; Hassanain et al., 2010), housing services by (Ibem, 2011) and basic services by (Ibem, 2013) while Fatoye & Odusami, 2009 list a number of performance indicators without indicating a descriptive terminology for the element. Housing support services is a more descriptive and definite term.

Table 17. Synoptic overview of studies on support services

Study terminology	Reference	Building type	Methodology
Support services	Hassanain, 2008	Dormitory	Personalised survey
Support Services/Utilities, Parking, Children Playground, Landscape	Hassanain et al., 2010	Residential	Questionnaires
Housing Services	Ibem, 2011	Residential	Questionnaires
Basic Services	Ibem, 2013	Residential	Questionnaires
-	Fatoye & Odusami, 2009	Residential	Personalized questionnaires

Housing support services are water supply, sanitary services and electrical services (Ibem, 2011). Facilities such as bathrooms, showers, and water closets, good mechanical ventilation should be provided. Hot and cold water supply and waste discharge systems should be properly installed, maintained, and managed. All electrical and mechanical fittings and equipment should be easily maintained. Services such as electricity supply and hot water must be adequate for the level of use (Hassanain, 2008). Ensuring that these performance indicators are satisfactory will require a walkthrough assessment or questionnaire survey; a number of performance indicators are identified through a review of previous studies as follows:

- Stability of power (Liu, 1999; Hassanain, 2008; Ibem, 2011)
- Adequacy of power sockets (Hassanain, 2008)
- Flexibility of IT connection points (Hassanain, 2008)
- Number of washroom facilities (T/B)/Adequacy of washroom facilities (Liu, 1999; Fatoye & Odusanmi, 2009; Hassanain, 2008; Hassanain et al., 2010; Ibem, 2011; Inah et al., 2014)
- The number and position of electrical sockets (Fatoye & Odusanmi, 2009; Hassanain et al., 2010)
- The operation of electrical fittings (Liu, 1999; Fatoye & Odusanmi, 2009; Inah et al., 2014)
- The functioning of plumbing fittings (Ukoha & Beamish, 1997)
- The operation of windows (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusanmi, 2009; Hassanain, 2008; Hassanain et al., 2010)
- The operation of doors (Ukoha & Beamish, 1997; Fatoye & Odunsanmi, 2009; Hassanain, 2008; Hassanain et al., 2010; Inah et al., 2014)
- Windows for kitchen or bathroom (Fatoye & Odunsanmi, 2009)
- Accessibility to disabled and aged people (Liu, 1999; Fatoye & Odunsanmi, 2009)
- Adequacy of off-street parking (Fatoye & Odunsanmi, 2009)
- Storm-water drainage system (Fatoye & Odunsanmi, 2009; Inah et al., 2014; Hassanain et al., 2010; Ibem, 2011)
- Refuse disposal system/ Cleanliness and trash removal (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusanmi, 2009; Hassanain, 2008; Inah et al., 2014; Hassanain et al., 2010; Ibem, 2011)
- Street lightning (Liu, 1999; Fatoye & Odusami, 2009; Ibem, 2011; Hassanain et al., 2010)

- Open spaces, parks and reserves (Liu, 1999; Fatoye & Odunsanmi, 2009; Hassanain et al., 2010; Inah et al., 2014)
- Design of on-site car parking space is efficient (roof, space arrangement) (Ukoha & Beamish, 1997; Hassanain et al., 2010)
- Adequacy of artificial lighting levels in the car parking space (Liu, 1999; Hassanain et al., 2010)
- Availability of good roads and sidewalks (Inah et al., 2014; Ibem, 2011; Hassanain et al., 2010)
- Efficiency of insect spray services (Hassanain et al., 2010)
- Capacity of utility systems (sewage, electrical, water supply and gas) (Liu, 1999; Hassanain et al., 2010)
- Availability and quality of drinking water (Liu, 1999; Hassanain et al., 2010; Ibem, 2011)
- Quality and capacity of provided refrigerator (Hassanain et al., 2010)
- Quality and capacity of stove, oven and kitchen exhaust vent (Hassanain et al., 2010)
- Quality and capacity of washing machine (Hassanain et al., 2010)
- Television transmission (Liu, 1999)
- Quality of Lifts (Liu, 1999)

C. Behavioural Performance Elements

This pertains to the social, psychological, cultural and aesthetic level. Behavioural elements link occupants' activities with the physical environment. Typical issues include: how the size of an area and number of persons sharing it affect the building occupants? Does the functional distance between areas in a facility affect the frequency of use? Does the configuration of circulation routes affect social interaction? What features will best provide an appropriate image for a building? What design attributes provide for the occupants' perception of both an understandable and stimulating building? How can a satisfactory level of privacy as well as social interaction be developed for building occupants? These are some of the questions that are addressed by behavioural elements, and their physical design responses are rooted in the careful programming of buildings (Preiser et al., 1988).

C.1 Privacy and Territoriality

This is an element that is specific to the behavioural character of occupants'. The ability to control space by individuals or groups including physical, visual, and aural access defines the level of privacy or interaction that can be achieved. The design of walls, openings and access are factors that influence the level of privacy in a space. Privacy and territoriality is particularly important for housing offices and outdoor urban spaces (Preiser et al., 1988). This element is described by Ibem, 2011 and Inah et al., 2014 as Level of Privacy, Preiser et al., 1988 used the terminology "Privacy and Territoriality" since it also involves the occupants' satisfaction with the ability to control space. The following are a list of indicators identified by previous research to subjectively evaluate this element:

- The level of privacy in your house (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014)
- Privacy from your neighbours (Liu, 1999)
- Distance of your building from your side boundary fence (Fatoye & Odusami, 2009)
- Distance of your building from the rear boundary fence (Fatoye & Odusami, 2009)
- Building setback (Fatoye & Odusami, 2009; Inah et al., 2014)
- Density of population within the estate (Liu, 1999)

C.2 Location

The location of a building and its proximity to places of interest is a major factor in the satisfaction of its occupants (Hassanain, 2008; Fatoye & Odusami, 2009). It is also described as “Proxemics”, the study of interpersonal distances maintained among individuals for purposes of communication. Such distances vary by culture, sex, activity, and age (Preiser et al., 1988). The housing facilities in a campus should be located in reasonable proximity (i.e. within short walking distance) to teaching, recreational, food-consuming, and car parking facilities (Hassanain, 2008). A synoptic review of studies presented in table 18 shows the various terminologies, case-studies and methodologies used by various researchers. Terminologies include: Proximity to other facilities on campus (Hassanain, 2008) and Ease of access to local facilities and city wide services (Fatoye & Odusami, 2009).

Table 18. Synoptic overview of studies on location

Study terminology	Reference	Building type	Methodology
Proximity to other facilities	Hassanain, 2008	Dormitory	Personalised survey
	Inah et al., 2014	Residential	Questionnaires
Ease of access to local facilities and city wide services	Fatoye & Odusami, 2009	Residential	Personalized questionnaires

Performance indicators can be assessed by driving through the neighbourhood to assess the distances between various facilities and through questionnaire survey to find out occupant's perception of these distances. A list of indicators based on reviewed literature is as follows:

- Location of House in estate (Ukoha & Beamish, 1997; Hassanain et al., 2010; Ibem, 2011)
- Nearness to place of worship (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014)
- Nearness to children's schools (Liu, 1999; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014)
- Nearness to the market and shopping centres (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusami, 2009; Inah et al., 2014; Ibem, 2011)
- Nearness to recreational facilities (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusami, 2009; Ibem, 2011)
- Nearness to your workplace (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014)
- Nearness to medical facilities (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014)
- Postage Services (Liu, 1999)
- Nearness to fire fighting station (Fatoye & Odusami, 2009; Inah et al., 2014)
- Nearness to transportation amenities (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusami, 2009; Ibem, 2011)
- Nearness to the police station (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009; Inah et al., 2014)
- Size of estate (Liu, 1999)
- Appropriateness for residential buildings (Liu, 1999)
- Position of building relative to campus restaurant (Fatoye & Odusami, 2009)
- Position of building relative to academic facilities (Fatoye & Odusami, 2009)
- Position of building relative to sports facilities (Fatoye & Odusami, 2009)
- Extent of social relation among neighbours (Ukoha & Beamish, 1997; Ibem, 2011; Inah et al., 2014)

- Prices of goods and services in the housing estate (Ibem, 2011)
- Job/Business opportunities within and around the housing estate (Ibem, 2011)
- Level of crime and anti-social activities in the housing estate where you live (Ibem, 2011)
- Suitability to natural way of life (Ibem, 2011)
- Rule and regulations of housing estate (Ukoha & Beamish, 1997; Ibem, 2011)

C.3 Appearance

Appearance is one of the most important aspects of building performance. It deals with the aesthetic perception of occupants of their buildings (Preiser et al., 1988). Common problems that impact exterior walls are colour fading, moisture and wind infiltration, spalling, buckling, delamination, cracking, cleanability and erosion. The quality of construction and selection of building materials should be compatible with, and complement, the existing physical environment (Hassanain, 2008). Thus appearance can be a function of effective housing management and maintenance, though it has been evaluated independently by (Hassanain, 2008) as Interior and Exterior finish systems and (Hassanain et al., 2010) as Finish Systems and Furniture, see table 19. Appearance as defined by (Preiser et al., 1988) is a more encompassing term.

Table 19. Synoptic overview of studies on appearance

Study terminology	Reference	Building type	Methodology
Interior and Exterior finish systems	Hassanain, 2008	Dormitory	Personalised survey
Finish Systems and Furniture	Hassanain et al., 2010	Residential	Personalised survey
-	Fatoye & Odusami, 2009	Residential	Personalized questionnaires

Performance indicators can be assessed through a walkthrough Inspection to assess the quality of materials and presentation of the interior and exterior of the housing, and also through questionnaire surveys. The performance indicators highlighted by previous research include the following:

- Toilet design and quality (Fatoye & Odusami, 2009)
- Quality of building materials (Inah et al., 2014; Ibem, 2011)
- Kitchen design and quality (Fatoye & Odusami, 2009; Hassanain et al., 2010)
- Bathroom design and quality (Fatoye & Odusami, 2009; Hassanain et al., 2010)
- Quality of materials used in floors (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009)
- Quality of materials used in ceilings (Fatoye & Odusami, 2009)
- Quality of materials used in walls (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009)
- General aesthetic appearance (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusami, 2009; Ibem, 2011; Inah et al., 2014; Hassanain et al., 2010)
- Quality of paints (Ukoha & Beamish, 1997; Fatoye & Odusami, 2009)
- Quality/Colours used in exterior of the house (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odunsanmi, 2009; Hassanain, 2008; Hassanain et al., 2010)
- Quality/Colours used in interior of the house (Ukoha & Beamish, 1997; Fatoye & Odunsanmi, 2009; Hassanain, 2008; Hassanain et al., 2010)
- Quality and Presentation of finishes in common spaces (Hassanain, 2008)
- Streets design (Fatoye & Odusami, 2009; Hassanain et al., 2010)
- Green areas (vegetation) (Fatoye & Odusami, 2009; Hassanain et al., 2010)
- Environmental sanitation (Fatoye & Odusami, 2009; Hassanain et al., 2010)
- Landscaping of neighbourhood (Ukoha & Beamish, 1997; Liu, 1999; Fatoye & Odusami, 2009; Hassanain et al., 2010)
- Quality of children playing ground (Ukoha & Beamish, 1997; Ibem, 2011; Hassanain et al., 2010)

3.5.3.2 Summary and Discussion

And extensive review of literature of various performance elements in the evaluation of buildings shows that a holistic approach is still unpopular. Various researchers employ few techniques and only evaluate a set of performance elements. Their studies do not present a comprehensive evaluation, and thus can best be described as impartial. Worthy of note also is the fact that researchers do not agree on terms and definitions of performance elements taken into consideration in their research. Table 20, 21 and 22 below presents a summary of the preferred terminologies for this research, referenced definitions and measurement methods.

Table 20. Definition and measurement for the technical performance elements

A. Technical Performance Elements		
Elements	Definition	Measurement methods
A1. Thermal Comfort	“the state of mind that expresses satisfaction with the surrounding thermal environment” (ASHRAE 55, 2004)	– Walkthrough to identify maintenance issues or behavioural patterns of users – ASHRAE 55, 2004: Physical Measurement of: Temperature, Relative humidity, Air velocity, Temperature of the walls that surround the indoor environment (MRT) according to Fanger’s theory. – Questionnaire Survey of occupant, 90% of occupants should be satisfied
A2. Indoor Air	“the comfortable range of the temperature, humidity, ventilation and	– ASHRAE 62.1, 2004: CO2 concentrations <700 ppm above the

Quality	chemical or biological contaminants of the air inside a building" (Anderson et al., 2014)	outdoor air concentration. Humidity recommended to be between 30% and 60% - Questionnaire Survey of occupants, 80% satisfaction of untrained observers
A3. Visual Comfort	The adequacy of lightning to provide visibility; and the elimination of disturbing effects like discomfort glare (Dall, 2013).	- IESNA, 2000: visual tasks of medium contrast or small size (500-1000 Lux) - Questionnaire Survey of occupants
A4. Acoustic Comfort	It covers the ambient level of sound, the transmission of sound between areas and rooms, reverberation, and specific areas such as machine noise and auditorium acoustics (Preiser et al., 1988).	- Department of Defense, 2003:Noise Criterion Range for residences and apartments (NC-20 TO NC-30) - Questionnaire Survey of occupants
A5. Security and Safety	The protection and securing of residents and their property, prevention of anything that may threaten them, investigation of crimes and community participation in efforts to address causes of crime" (http://www.etu.org.za/toolbox/docs/government/safety.html)	- Walkthrough Inspection to assess compliance with local and international requirements including International Building Code (IBC) 2012. - Questionnaire Survey of occupants
A6. Health	Sustenance of the activities of building occupants, and preventing SBS (Sick Building Syndrome) and BRI (Building Related Illnesses); including symptoms such as headaches, eye, nose, and throat irritation, coughing, nausea, dizziness, and difficulty in concentration (Anderson et al., 2014).	- Questionnaire Survey of occupants
A7. Management	"Work needed to keep a dwelling at or	- Assessment of building physical

and Maintenance	to restore a dwelling to an acceptable standard, and also includes minor improvements" (van Mossel and Jansen, 2010).	characteristics, services and environment, and compliance with codes, standards or bye-laws – Questionnaire Survey of occupants

Table 21. Definition and measurement for the functional performance elements

B. Functional Performance Elements		
Elements	Definition	Measurement methods
B1. Layout, furniture and spatial Comfort	Spatial comfort entails the layout of space, furniture, and storage and the convenient circulation and accessibility to various usable spaces within a building (Hartkopf et al., 1986)	– Walkthrough Inspection to assess the quality, arrangement and adequacy of furniture – Questionnaire Survey of occupants
B2. Housing Support Services	Housing support services are water supply and sanitary services and electrical services (Ibem, 2011)	– Walkthrough Inspection to assess the quality, accessibility and adequacy – Questionnaire Survey of occupants

Table 22. Definition and measurement for the behavioural performance elements

C. Behavioural Performance Elements		
Elements	Definition	Measurement methods
C1. Privacy and Territoriality	The ability to control space by individuals or groups including physical, visual, and aural access, defines the level of privacy or interaction that can be achieved (Preiser et al., 1988)	– Questionnaire Survey of occupants

C2. Location	“Proxemics is the study of interpersonal distances maintained among individuals for purposes of communication. Such distances vary by culture, sex, activity, and age” (Preiser et al., 1988).	– Drive through the neighbourhood to assess its proximity to available facilities – Questionnaire Survey of occupants
C3. Appearance	It deals with the aesthetic perception of occupants of their buildings (Preiser et al., 1988).	– Walkthrough to access the physical presentation of the building’s interior and exterior – Questionnaire Survey of occupants

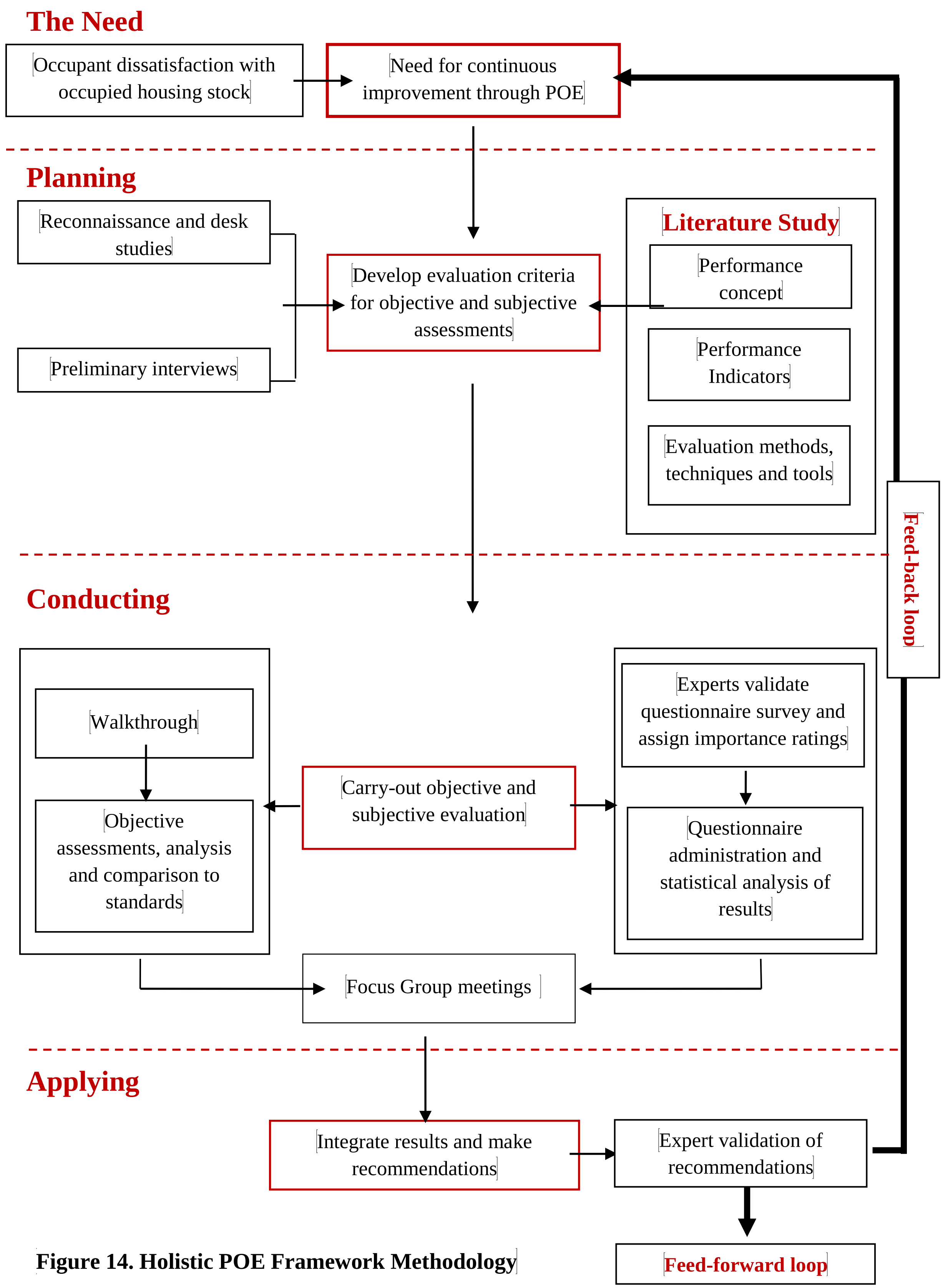


Figure 14. Holistic POE Framework Methodology

3.5.4 Applying Phase

It is important to know that many designers and managers are not interested in what research results say, but rather in being shown what research demonstrates design should do. Managers or architects do not feel they have the time to read research reports, but are very glad when design directions are being given based on results (Preiser, 1989). Previous research already discussed did not show-case a feed-back technique of recommendations made for the industry. The use of advanced statistical packages or theorems for example presents results in a way of little benefit to building owners, designers and facility managers. This problem was noted by Mohsini, 1989. A value-based approach to recommendation and feed-back, which is not about elevating the status of mathematicians or statisticians, will ensure feed-back is made which can be adopted by its intended audience.

Also, benchmarking against similar empirically derived yardsticks is now a standard requirement for energy and occupants. Benchmarks however are not easily achieved due to the few number of POE studies carried within a geographical area. At least 30 studies are needed within the same geographical area for meaningful comparison (Leaman et al., 2010).

3.6 Research Design and Methodology

The method used for this study is a combination of multiple techniques according to the research objective which is to develop a holistic POE tool. Thus surveys, physical observations, interviews, and focus group meetings were employed as research methodology for this study. As shown in figure 14 a POE study consists of three stages planning, conducting and applying. The research design is however broken down into the following stages:

- Literature review
- Expert questionnaire survey
- Walkthroughs
- Pilot study with occupants
- Occupants' satisfaction survey
- Physical measurements
- Focus group meetings
- Professional interviews to validate POE recommendations

3.6.1 Identification of Performance Elements and Indicators

The outcome of an extensive literature review of performance indicators employed in the subjective evaluation of residential buildings is presented in figures 16 - 19. This was subsequently compiled into a list of performance indicators categorized under various performance elements defined in tables 20 – 22, which were also classified under three categories: technical, functional and behavioural categories. See figure 7 and figures 16 -19. This initial collection of questionnaire has also been refined with a preliminary interview made with three (3) occupants of the residential housing to be evaluated in this research. See Appendix E for the preliminary interviews. This was to ensure that performance indicators have been comprehensively included, and the questions have been framed to an acceptable level of clarity. The result was a comprehensive list of 183 feasible performance indicators.

3.6.2 Expert Questionnaire Survey

The performance indicators thus identified have been presented in the form of questionnaires (See: Appendix F-J) to be evaluated by professional experts with relevant experience in the residential housing context, preferably over ten (10) years. Experts may decide that some questions are not relevant for the domestic building context, while issues arising from their previous experience may inform the need to include some questions as indicators, and also they may decide to rephrase existing questions to make it simpler to the respondents. For this purpose, the questionnaire has been divided into specific groups of indicators according to five (5) relevant professional categories. These include:

- Appendix F: "Indoor Environment": consisting of indicators pertaining to issues of Indoor Environmental Quality, including: thermal comfort, indoor air quality, acoustical comfort, visual comfort.
- Appendix G: "Safety and Security"
- Appendix H: "Building Maintenance"
- Appendix I: "Health"
- Appendix J: "Planning and Architecture" the most extensive questionnaire and consists of indicators including layout, furniture and spatial comfort, support services, privacy and territoriality, location, and appearance.

Based on the premise that the performance evaluation indicators will not all contribute equally to health, well-being, comfort and overall satisfaction of building occupants. Expert questionnaire surveys will also be used to derive relative importance indices of the performance indicators gathered. A minimum of three (3) professionals with respect to the individual building performance evaluation elements, with no less than five (10) years of relevant professional experience in the domestic residential housing context will be selected for the study. See table 27. The survey consists of importance ratings ranging from (1) Slightly Important to (5) Extremely Important, table 23 shows the importance ratings and their corresponding numerical value. The geometric mean values thus calculated represent an indicator's Relative Importance Index (RII).

Table 23. Importance ratings for expert questionnaire survey

	Importance ratings
1	Slightly Important
2	Minor Importance
3	Important
4	Very Important
5	Extremely Important

Expressed arithmetically, the RII is calculated using the following formula

$RII_i = \frac{\sum_{i=1}^{N} x_i}{N}$ .... Eq. (1)

Where:

RII_i = Relative Importance Index for indicator (i).

x_i = Importance rating given for indicator (i).

N = Total number of professional respondents.

3.6.3 POE Data Collection and Analysis

The data collection methods employed in this research includes a review of existing documents, walkthroughs, physical measurements of Indoor Environmental

Quality (IEQ), questionnaires and interviews. These data collection methods are discussed in more detail below:

3.6.3.1 Review of Existing Documents

This entails the acquisition of relevant documents including the architectural drawings, specifications, and maintenance work orders. The review of these documents was used to develop the questionnaire tool, and also build the case study. A list of problems (see appendix D) reported by occupants of the residential housing facility to the campus maintenance department was used in this study as a substitute for the maintenance work order. The floor plans for both 4 and 5 bedroom apartments are also attached in appendix C. These documents were also referred in the analysis of POE questionnaire responses and making POE recommendations.

3.6.3.2 Walkthroughs

As explained in section 3.3.1, a walkthrough is a tour around the facility to identify issues and problematic elements. This was recorded by still images using a digital camera (see photos in appendix B). The walkthrough was carried out by moving from space to space within the building from the ground floor to the first floor. A walk through the neighbourhood was also conducted.

3.6.3.3 Spot Measurements

Spot measurements was carried out for Carbon Oxide (CO), Carbon dioxide (CO_2), particles, lighting levels, sound levels, air temperature, relative movement, and air velocity. The instruments used for this exercise are listed in table 24. The study was conducted in December, 2014 during the winter season.

Table 24. Instruments used for spot measurements

Name of instruments	Uses	Measurement Type	Placement Position
Thermohygro anemometer	Temperature and Relative Humidity	Spot measurement	Four locations (at the corners and centres) held at the level of sitting/sleeping/working in living spaces
TSI Optical Particle Sizer 3330	Particle Measurement		
Graywolf Direct Sense IAQ Monitor	Carbon dioxide and Carbon monoxide		
Sound Level Metre, SL 130G EXTECH	Acoustic		
HD 450 EXTECH	Light		

The exercise was carried out in mid-day, it started around 11.00 am and ended at 2.00 pm. Light measurements were made around working areas and at the centre of living spaces and the average readings were recorded. Readings were also taken for a combination of natural and artificial lighting in some living spaces. Carbon dioxide, carbon monoxide and particulate measurements were made at the interior and exterior of exits to access any potential for infiltration. Noise measurements were taken at possible ear positions within living spaces and the most critical value was selected.

3.6.3.4 Occupants' POE Questionnaire

A list of performance indicators has been identified through literature review totalling 217 performance indicators as presented in figures 16, 17, 18 and 19. This was thus validated and reviewed by industry professionals as explained in section 3.6.2 and resulted in the questionnaire tool presented in appendix K with 193 performance indicators. 'Health' as a performance element was removed all together since it was identified by 2 medical doctors as not being an important element in assessing the performance of domestic housing facilities. Ten performance elements were also identified as 'not applicable' to the case study according to a pilot-study conducted with potential respondents. The questionnaire in appendix K consists of two parts: respondent's background; and the questionnaire survey.

The questionnaire was designed using a likert scale of 1 – 5 as presented in table 25. Open-ended sections were also appended to each performance element to derive more qualitative feedback from respondents. The results of the open ended section of the questionnaire are presented in appendix L. The questionnaire survey also includes a section where the demographic characteristics of the respondents are recorded. The demographic characteristics captured in this study include: name, sex, age, nationality, length of stay in the house, nature of occupants, and number of hours spent daily in the house. The results of the demographic characteristics of occupants are presented in section 4.2, table 28.

Table 25. Likert scale for occupants' questionnare tool

	Level of Satisfaction
1	Very Dissatisfied
2	Dissatisfied
3	Neutral
4	Satisfied
5	Very Satisfied

Sloven's formula (equation 2) was used to determine the minimum number of respondents to make the study statistically valid. The effective population size for this study was 90, this was based on the occupancy records obtained from the campus housing administrative department of KFUPM.

$$n = \frac{N}{1+Ne^2} \qquad \text{.................... Eq. (2)}$$

Where:

n = sample size

N = population size

e = sample error

For a sample error (e) of 0.15, that is 85% confidence that the sample size will accurately represent the population, n (sample size) will be equal to 30. Fellows and Liu, 2009 suggest that: "large number statistics require n ≥ 32" as a rule of thumb. In this study a sample size of 35 has been adopted for a population size of 90. Questionnaires were administered to occupants of all 90 residential villas through e-mails, postal mails, and follow up calls. The questionnaire responses were collected over a period of two months.

3.6.3.5 Data Analysis

The data received has been analysed through a combination of descriptive and inferential statistics. Descriptive statistics of the results are presented in tables 29-32 and tables 34-40. These tables show the Relative Importance Index (RII) calculated according to equation 1, the total number of respondents for each indicator (N), the Mean Satisfaction Index (MSI) calculated using equation 3, and finally the standard deviation (SD). All calculations were made with the aid of Minitab statistical software package. The overall satisfaction of the occupants with each performance indicator was judged by the neutral value of '3.00' according to Mohit & Azim, 2012. Thus MSIs above '3.00' was judged as an indication of satisfaction and MSIs below '3.00' was judged as an indication of dissatisfaction.

The data was further plotted on an Importance-Satisfaction (IS) analysis matrix to compare between RII and MSI. The IS matrix is an adoption of the importance-performance analysis matrix originally introduces by Martilla & James, 1977. This approach measures satisfaction against importance on a 2-dimensional grid to provide a graph with four distinct regions. See figure 15. It has the particular advantage prioritizing what action need to be taken (Alves et al., 2009). The means of residential satisfaction and importance ratings of performance indicators are plotted on the x and y axis respectively. The four quadrants that emerge from the plot are described as follows (Matzler et al., 2004; Alves et al., 2009; http://www.tbs-sct.gc.ca/si-as/tools-outils/tools-outils04-eng.asp):

i. STRENGHTS: indicators are above average importance and above average satisfaction, and represent opportunities for gaining or sustaining competitive advantage. In this area the service provider should "keep up the good work" and little or no improvement is required.

ii. PRIORITIES FOR IMPROVEMENT: indicators are above average importance and below average satisfaction. This requires immediate attention, thus service providers should "concentrate here".

iii. OPPORTUNITIES: indicators are below average importance and below average satisfaction, thus it is not required to focus additional effort here. Performance indicators that fall in this category are described as being of "low priority" for improvement.

iv. REDEPLOY: indicators are blow average importance and above average satisfaction and are described as a "possible overkill". This implies that no improvement is required in this regard, and so resources committed to performance indicators in this category can be reallocated to priorities for improvement

Figures 29, 30, 31 are IS matrix plots for performance indicators in the technical, functional and behavioral category respectively.

$$MSI_i = \frac{\sum_{i=1}^{N} y_i}{N} \qquad \text{.................... Eq. (3)}$$

Where:

MSI_i = Mean Satisfaction Index for indicator (i).

y_i = Satisfaction rating given for indicator (i).

N = Total number of professional respondents.

Before conducting inferential statistics, the overall residential satisfaction for each respondent was calculated according to (Mohit et al., 2010)'s methodology shown in equation 4. This is through the calculation of the mean response of all performance indicators for a respondent (say R_1). Mohit et al., 2010 also proposed a regime of satisfaction to include 20-39 = very low; 40-59 = low; 60-79 = moderate; and 80-100 = high. This scale can also be used to interpret the overall residential satisfaction of each respondent using the calculated SI_r values. The results are presented in table 41, and a normal probability plot of the result is presented in figure 32.

$$SIr = \frac{\sum_{i=1}^{N1} ai + \sum_{i=1}^{N2} bi + \sum_{i=1}^{N3} ci + \cdots + \sum_{i=1}^{Nn} ni}{\sum_{i=1}^{N1} Ai + \sum_{i=1}^{N2} Bi + \sum_{i=1}^{N3} Ci + \cdots + \sum_{i=1}^{Nn} Ni} *100 \qquad \text{................. Eq. (4)}$$

Where:

SI_r= Satisfaction Index of a respondent

N_1, N_2, N_3 and N_n = number of variable selected for scaling under each component of residential environment

ai, bi, ci and ni = actual score of a respondent on the ith variable in the component

Ai, Bi, Ci and Ni = the maximum possible scores for the ith variable in all performance elements

The values derived for (SI_r) Satisfaction Index of a respondent was used to carry out a two-T test analysis based on the hypothesis that two groups formed based on their occupancy profile have similar views about their residential environment. i.e. the difference between the means of the two groups will be zero. The two groups formed are: the respondents 'with more adults'; and respondents 'with more children'. T-tests are usually conducted with 95% confidence level ($p = 0.05$), if the test at that level is passed, a higher level may be tested or vice versa. The 95% confidence level indicates that, although the data support the conclusion with 95% probability, there is a 5% chance that the conclusion is wrong (Fellows & Liu, 2008). A sample size of 10 was drawn for both groups each. The result is discussed in section 4.2.2.1.

A multi linear regression (MLR) analysis was also carried out to measure the simultaneous effect of two or more predictor variables to explain the variation in the dependent variable using the stepwise method. Equation 5 is the representation for the multi linear regression model for a predicted outcome value y, and predictor variables x_1, x_2, x_3 ... x_n multiplied by a co-efficient $\beta 1$, $\beta 2$, $\beta 3$ ... βn respectively. The values of β represent the amount of contribution of each predictor (or independent variable) to the predicted (or dependent) variable.

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_n x_n \qquad \text{................ Eq. (5)}$$

In this study the satisfaction index calculated for each respondent according to equation 4 is the predicted (or dependent) variable. A list of 20 performance indicators was selected to serve as independent variables for the regression analysis. These indicators were selected based on the results of previous analysis techniques in which they have been identified as the main contributing performance indicators to overall residential satisfaction. The results and discussion for the MLR analysis is presented in section 4.2.2.2.

3.6.3.6 Focus group meetings

A focus group meeting was carried out to draw out more qualitative information from the respondents. Eight selected issues identifies from other evaluation techniques was discussed with four occupants of AlMarooj courts. These respondents were selected to be representative of the broad spectrum of occupants of the AlMarooj courts. They include: a Sudanese; a Saudi; a Pakistani and an Egyptian. The specific issues identified for discussion based on results from other analysis techniques are: 'HVAC system'; 'lightning system'; 'size of maid's bedroom'; 'size of washroom in masters bedroom'; 'availability of shower facility on the ground floor'; 'availability of parks and open spaces'; 'privacy'; and 'use of driver's lodge'.

Due to difficulties faced in trying to bring all four participants to gather together for the focus group meeting, it was decided to meet individually at their convenient times and to discuss the specific issues highlighted. The results of this exercise are presented in section 4.3.

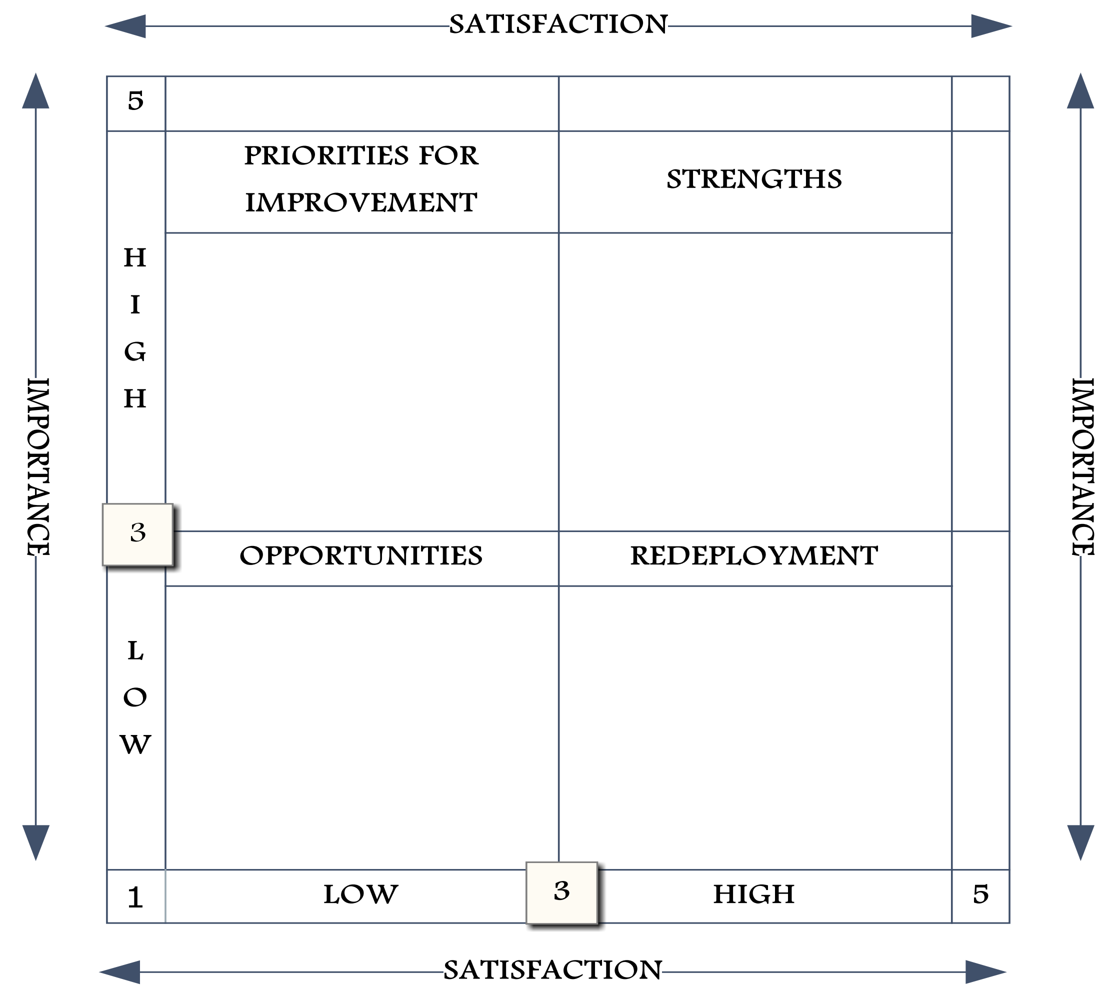


Figure 15. Importance-Satisfaction matrix Key (As is: http://www.tbs-sct.gc.ca/si-as/tools-outils/tools-outils04-eng.asp)

Category	Performance Elements	Indicators
Technical Performance Elements	Thermal Comfort (10 Indicators)	Indoor Temperature in winter; Indoor Temperature in summer; Indoor Temperature shifts (stability); Indoor Humidity; Air movement; Incoming sun; Drafts from windows/vents; Location/Accessibility of thermostat; Control of thermostat, Overall satisfaction with thermal comfort
	Indoor Air Quality (9 Indicators)	Adequacy of natural ventilation; Adequacy of mechanical ventilation; Air freshness in summer; Air freshness in winter; Odour/Air pollution; Odour/Air pollution; Odour/Air pollution; Air Flow; Overall satisfaction with indoor air quality
	Acoustic Comfort (8 Indicators)	Noise from neighbours; Noise from people between rooms; Noise from vehicles outside; Noise from air/HVAC system; Noise from lighting fixtures; Other noise from outside the building; Control over noise; Overall satisfaction with noise
	Visual Comfort (11 Indicators)	Amount of daylight (natural lighting); Illumination level/How bright are the lights (artificial lighting) in the living room; Illumination level/How bright are the lights (artificial lighting) in the bedrooms; Control/Use of Electric lighting; Control of day lighting; Glare from lights; Exterior lighting levels in the night; Adequacy of lighting levels in the corridors of the building; View to outside; Overall visual quality in the house during the day; Overall visual quality in the house in the night

Figure 16. Performance Indicators for the Technical Performance Elements (a)

Category	Performance Elements	Indicators
Technical Performance Elements	Safety and Security (15 Indicators)	Security system of your house; Quality and perception of fire safety systems in the building; Ease to identify Emergency/Escape route; Ease of exiting the building in cases of fire emergencies; Ease to identify and reach fire alarm systems; Anti-crime measures; Level of security in the neighbourhood; Level of safety measures in children playground areas; Level of safety measures in streets and walkways; Availability of emergency preparedness measures in outdoor planning; Enforcement of maximum speed limit rules; Quality of provided speed pumps; Quality of landscape design in facilitating safe driving; Protection against insects and dangerous animals; Overall satisfaction with safety and security
	Management and Maintenance (32 Indicators)	Maintenance of building components: Exterior paintwork; Hinges and locks of windows and external doors; Kitchens; Drains; Toilets; Bathrooms; Shared areas; Balconies; Entrance hall; Gallery; Corridor and/or stairs; Maintenance of installations: Heating and water systems; Ventilation systems; Lighting in shared areas; Lifts; Maintenance of surrounding grounds: Paving around the building; Communal greenery; Management issues: Treatment of residents; Handling of residents' complaints; Management response to necessary repairs; Management team's resources to do the job; Ease to contact maintenance department; Maintenance team keep residents informed; Maintenance team provides good value for money; Frequency of house maintenance; Speed and efficiency of maintenance services for indoor facilities; Others: Ease (and cost) of maintenance of house; Low-cost maintenance features in your house; Level of Deterioration in building; Overall satisfaction with management and maintenance of facilities in the housing estate
	Health (9 Indicators)	Skin reaction (irritation, itchiness, dryness, reddening, rashes); Eyes (irritation, itchiness, dryness, watering); Nose (irritation, itchiness, congestion, sneezing, nasal, excretion); Throat (irritation, dryness, coughing); Chest (breathing difficulties, wheezing, tightness of chest); Headaches; Lethargy; Tiredness; Overall perception of apartment's effect on health

Figure 17. Performance Indicators for the Technical Performance Elements (b)

Category Performance Elements Indicators

Category	Performance Elements	Indicators
Functional Performance Elements	**Layout, Furniture and Spatial Comfort (37 Indicators)**	Type of House; Plot size; Adequacy of circulation routes around the building; Space for landscaping; No of rooms in your house; Location of rooms in your house; Suitability of the location of bathrooms relative to guest reception area; Room performance/Layout of the rooms; Functionality in design; Vertical circulation within building; Horizontal circulation within building; Scale and proportion of the floor plan; Ceiling height (head room); Size of individual spaces: Master Bedroom; Maid's Bedroom; Bedroom 1; Bedroom 2; Bedroom 3 (if applicable); Reception; Study room; Dining room; Family Living room; Personal storage/Capacity of Wardrobe; Overall satisfaction with amount of Space/Size of the rooms; Quality of carpentry work for: Doors and windows; Kitchen; Bathroom cabinets; Closets (wardrobe); Reception; Study room; Family dining room; Family living room; Master Bedroom; Maid's Bedroom; Bedroom 1; Bedroom 2; Bedroom 3 (if applicable)
	Housing Support Services (44 Indicators)	Stability of power; Availability and quality of drinking water; Adequacy of power sockets; Flexibility of IT/TV connection points; The type of electrical outlets used; The number and position of electrical sockets; The operation of electrical fittings; Operation of Windows; Windows for kitchen or bathroom; Effectiveness of windows in preventing dust; Operation of Doors; Operation of Door bell and opening system; Effectiveness of doors in preventing dust; The functioning of plumbing fittings; Number of washroom facilities (T/B)/Adequacy of washroom facilities; Size of T/B in Master Bedroom; Size of T/B in Maid's Bedroom; Size of T/B in Bedroom 1; Size of T/B in Bedroom 2; Size of T/B in Bedroom 3 (if applicable); Storm-water drainage system; Refuse disposal system/ Cleanliness and trash removal; Efficiency of insect spray services; Accessibility to disabled and aged people; Street lightning; Open spaces, parks and reserves; Availability and children's play-ground and ladies centre; Availability of good roads and sidewalks; Design of on-site car parking space is efficient (roof, space arrangement); Adequacy of off-street parking; Adequacy of artificial lighting levels in the car parking space; Capacity and Efficiency of utility systems: Sewage systems; Electrical; Water supply; Gas; Refrigerator; Stove; Oven; Kitchen exhaust vent; Washing machine; Dryer; Internet/Television connection points; Lifts

Figure 18. Performance Indicators for the Functional Performance Elements

Category	Performance Elements	Indicators
Behavioural Performance Elements	**Privacy and Territoriality (7 Indicators)**	The level of privacy within spaces in your house; Privacy from your neighbours; Distance of your building from your side boundary fence; Distance of your building from the rear boundary fence; Building setback; Density of Population within the estate; Overall satisfaction with privacy and territoriality
	Location (21 Indicators)	Size of estate; Appropriateness of location for residential buildings; Location of House in estate; Proximity/Nearness of your house to: Places of worship; Children's schools; Friends; Market and shopping centres; Recreational/Sport facilities; Workplace; Medical facilities; Fire fighting station; Transportation amenities; Police station; Restaurants; Library; Others: Extent of social relation among neighbours; Prices of goods and services in the housing estate; Job/Business opportunities within and around the housing estate; Level of crime and anti-social activities in the housing estate where you live; Suitability to natural way of life; Rule and regulations of housing estate
	Appearance (14 Indicators)	Design and quality of: Toilets; Kitchen; Bathrooms; Quality of materials used in: Floors; Ceilings; Walls; Paints; Others: Colours used in exterior of the house; Colours used in interior of the house; Quality and Presentation of finishes in common spaces; Streets and foot paths design; Green areas (vegetation); Landscaping of neighbourhood; General aesthetic appearance

Figure 19. Performance Indicators for the Behavioural Performance Elements

3.6.3.7 Expert Interview for POE recommendations

As explained in section 3.4, to generate valuable and realistic recommendations, a design office with a huge experience in design and consultancy for residential compounds in Saudi Arabia was consulted. An interview was conducted with an architect/project manager and also HVAC engineer to generate and validate solutions to problems identified by the study. The recommendations generated from this exercise were recorded and are presented in section 4.4.

3.7 Case Study Overview

Existing environments and products in use provides the best simulation models for evaluation studies (Preiser & Ostroff, 2001). POEs are contextual to case-studies and will lack a robust or real context without it, case studies provide: contextual information or reality; greater depth of qualitative data; opportunities for benchmarking performance; and learning opportunities from each project for all stakeholders involved (Turpin-Brooks & Vicars, 2006; Jamaludin et al., 2013). The King Abdul Aziz Centre for Science and Technology, Saudi Arabia in 2005 estimated the increase in duplex houses in Saudi Arabia to almost 25% increase in the next 20years. For Saudis in particular duplex houses provides the advantage of affordability in terms of cost and speed, as well as responsiveness to cultural and social needs. 53.6% of middle-income families prefer to live in detached houses because it provides privacy and freedom from sharing infrastructure and other facilities (AlSaati 2006).

The case study for this research is a conglomerate of duplex houses –AlMorooj Courts, owned and managed by King Fahd University of Petroleum and Minerals as a faculty housing facility. Its coordinates are 26°17'47.5"N 50°09'01.1"E within the university campus in Dhahran, Eastern Province of Saudi Arabia.

The Eastern Province is the largest province (710,000Km²) in Saudi Arabia. It is home to Saudi Arabia's oil production and world's largest oil company Saudi Aramco. The province is also home of the City of Jubail, which hosts the Jubail Industrial City - a global hub for chemical industries, and also a regional tourism area because of its location on the coast of the Persian Gulf and the variety of entertainment activities available across the province (http://en.wikipedia.org/wiki/Eastern_Province,_Saudi_Arabia). Dhahran (26.27 N latitude, 50.15 E longitude, and 17 m above sea level) is the major administrative centre of the Saudi Oil Industry; it is part of the Dammam metropolitan Area –the largest metropolitan area in the eastern province which consists of Dhahran, Dammam and Khobar. A number of fenced in compounds exists in Dhahran where expatriates live, with the largest being Saudi Aramco's residential camp with more than 9,700 residents (http://en.wikipedia.org/wiki/Dhahran). This compound shares a boundary fence with the King Fahd University of Petroleum and Minerals faculty residential housing facilities, one of which is AlMarooj courts consisting of 94 housing units, completed in 2008. See figures 20-23.

AlMarooj courts contains 34 units of 4 bedroom villas and 60 units of 5 bedroom villas. The floor plans are presented in appendix C. The ground floor comprises of the reception, dining room, study room, kitchen with laundry and storage, family living and family dining room. It also has two washroom facilities. The first floor is the sleeping area comprising of the bedrooms only, see table 26.

Table 26. Building's characteristics and specifications

Characteristics and specifications	Description
Location	Dhahran, 26.27 N latitude, 50.15 E longitude, and 17 m above sea level
Shape	Rectangular
Floor to floor height	3.5m
Floor area	227.46m2
Exterior walls	16mm plaster (dense) + 100mm concrete block (medium) + 50mm extruded polystyrene + 100mm concrete block (medium) + 13mm plaster (lightweight)
Roof	40mm concrete tiles (roofing) + 0.2mm polyethylene (high density) + 50mm extruded polystyrene + 4mm bitumen felt + 59mm cement screed + 300mm reinforced concrete (cast, dense)
HVAC system	Residential system (Constant-volume DX AC)

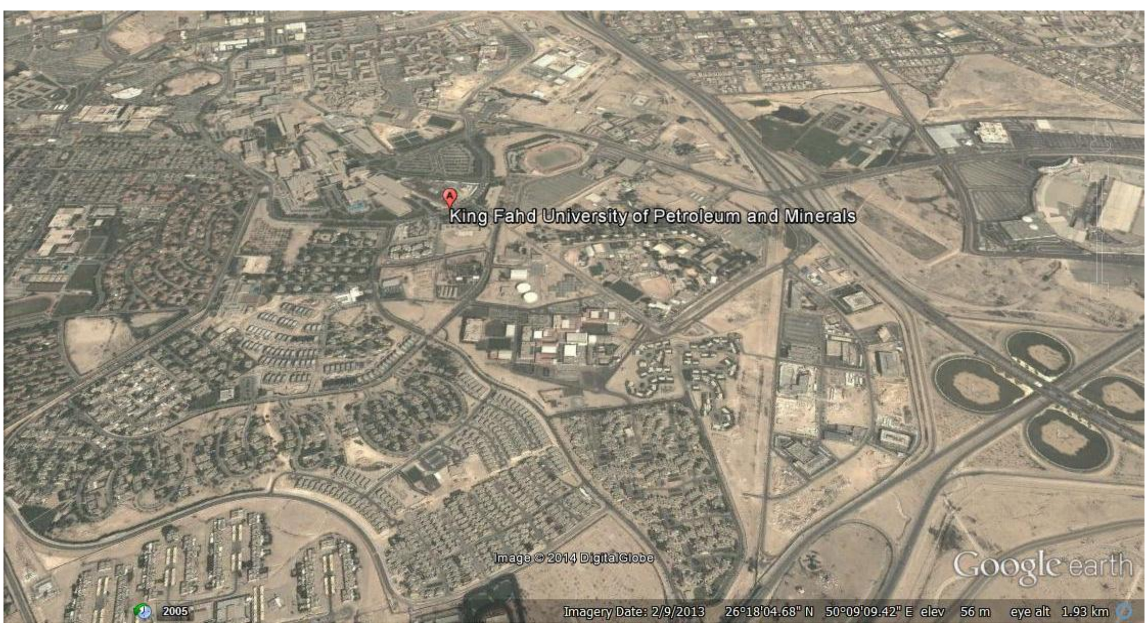


Figure 20. King Fahd University of Petroleum and Minerals master plan

Figure 21. Development plan for AlMarooj courts

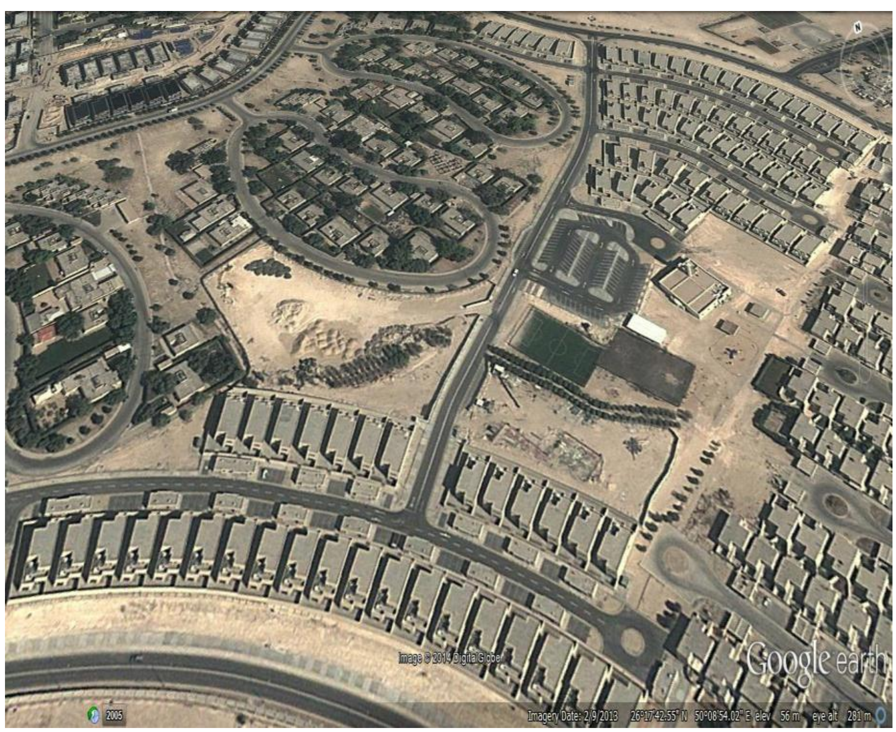


Figure 22. Aerial photograph of AlMarooj courts showing typical housing units

Figure 23. View of AlMarooj courts faculty residential housing units

The geographic characteristic of the city is a desert region which is hilly and rocky, and most of the earliest productive oil wells in Saudi Arabia were drilled in the area. Dhahran is characterized by long hot and humid summers. Winters, on the other hand, are short and mild, which makes hot and humid summer conditions the main concern for building designers. Temperatures can rise to more than 40 °C (100 °F) in the summer, coupled with extreme humidity (85—100%), given the city's proximity to the Persian Gulf (http://en.wikipedia.org/wiki/Dhahran). The city holds the record for the highest temperature in Saudi Arabia: 51.1°C (124 °F) as recorded in August 1956 (Budaiwi & Abdou, 2013). In winter, the temperature rarely falls below −2 °C (28 °F), with the lowest ever recorded being −5 °C (23 °F) in January 1964. Rain falls almost exclusively between the months of November and May. The "Shamal" winds usually blow across the city in the early months of the summer, bringing dust storms that can reduce visibility to a few meters. These winds can last for up to six months. On July 8, 2003, the dew point was 35 °C (95 °F) while the temperature was 42 °C (108 °F), resulting in a heat index of 68 to 71 °C (154 to 160 °F), one of the highest heat indexes in the world (http://en.wikipedia.org/wiki/Dhahran).

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, detailed discussion of the results is presented. The questionnaire compiled through a review of literature was validated by industry experts to check its clarity, comprehensiveness, redundancy and to derive importance ratings. The validated questionnaire was consequently administered to occupants of Al-Marooj Courts. Other evaluation techniques such as walkthroughs, spot measurements of Indoor Environmental Quality (IEQ) elements and focus group meetings have been carried out. The researchers have also been provided with a document listing all problems reported by the buildings' occupants to the maintenance department. The feed-back from these data collection processes have been analysed together in the following sections.

4.1 Expert Survey

The purpose of this survey is to validate the contents of the questionnaire, ensure it comprehensiveness and clarity. Respondents are also required to assign importance ratings to the indicators in the questionnaire survey. This validation process will ensure an effective application of the questionnaire and the reliability of the feed-back.

The respondents to the expert questionnaire include three architectural engineers, two architects, three project supervisors and two doctors. The respondents profile is provided in table 27. All professionals consulted have a minimum of five years experience and their professional experience is related to family residential facilities. The importance ratings given by the respondents where used to calculate the Relative Importance Index for all indicators in the questionnaire using equation 1, section 3.6.2. Results of the relative importance index are presented in tables (29-32) and (34-40).

Table 27. Experts' questionnaire respondents profile

Professional Respondents	Related Experience	Nature of facility: (single or multi-family) buildings	Size of facility (family units)
Architectural Engineer	5 – 10 years	Single-family	50 - 100
Architectural Engineer	5 – 10 years	Both	50 - 100
Architectural Engineer	10 – 20 years	Single-family	50 - 100
Architect	10 – 20 years	Multi-family	50 - 100
Architect/ Architectural Engineer	10 – 20 years	Both	➢ 500
Project Supervisor	5 – 10 years	Single-family	50 - 100
Project Supervisor	5 – 10 years	Both	100 - 500
Project Supervisor	5 – 10 years	Both	50 - 100
Medical Doctor	➢ 20 years	Single-family	➢ 500
Medical Doctor	➢ 20 years	Single-family	➢ 500

A number of indicators where edited or combined based on the recommendation of experts. Most significant amongst these is the performance element: 'Health' which was viewed by health professionals as not being significant to the residential context. Two medical doctors that where consulted pointed out that symptoms related to causes of the built environment have been from patients returning from Hajj or 'Umrah and not related to the housing facility.

Other performance indicators that have been removed from the initial questionnaire are: 'ease to identify and reach fire alarm systems'; 'availability of emergency preparedness measures in outdoor planning'; 'maintenance of shared areas, balconies, entrance hall, gallery, corridor and/or stairs'; 'lightning in shared areas', 'quality and presentation of finishes in common spaces'; and 'lifts'. These issues where identified as not been relevant to the single family residential housing context. Thus the validation of the questionnaire by experts with sufficient relevant background in the development and management of residential housing compounds/estates resulted in a comprehensive, reliable and effective questionnaire tool. The final questionnaire survey developed from this process contains 193 feasible performance indicators. See appendix K: Occupants' Questionnaire Survey. This tool needed to be customized to the specific residential context, which was done with a pilot survey of three occupants as discussed in the next section.

4.2 Occupants' Questionnaire Survey

The questionnaire tool developed from the previous section was further pilot tested with three occupants of Al-Marooj courts, they identified some issues that should be given proper consideration in the questionnaire survey, and this is presented in Appendix E: preliminary interview with building occupants. This interview was the basis for further editing of the questionnaire tool. Some of the indicators identified as not been applicable to the specific residential context include: 'level of safety measures in children playground areas'; 'quality of provided speed bumps'; 'maintenance team provides good value for money'; 'ease/cost of maintenance of house'; 'low cost maintenance features in your house'; 'sewage system', 'adequacy of gas', 'capacity and efficiency of dryer', ' proximity to fire fighting station, transportation amenities, police station'; 'prices of goods and services in the housing estate'; 'jobs/business opportunities within and around the housing estate'.

The total number of occupants residing in Al-Marooj courts is ninety (90) according to the housing administrative department. A representative sample was thus derived from this number with equation 2. All questionnaires were answered by the heads of the house-holds; these are professors working in King Fahd University of Petroleum and Minerals. This shows that all respondents are highly educated and male in gender. The respondents' nationality is diverse with the Saudis representing the highest percentage (23.53%). See figure 24. 33% of the respondents did not provide information about their nationality. Respondents from Canada and Jordan form the second largest group in this study with 9% each.

Majority of the respondents are within the age range of (50-60), that is (58.82%) percent and (40-50) with (23.53%) showing that they are middle-aged. See figure 25. Although families which are dominated by adult members (above 18 years of age) represent (67.65%) of the total population, families dominated by children represent a considerable percentage as well (29.41%). A large percentage of respondents (85.29%) have stayed in the housing for over 12 months followed by (35.29%) who have stayed for over 6 months but less than a year. Most of the respondents (64.71%) stay at home for more than 12 hours and (35.29%) are at home between 7 – 12 hours/daily. These statistics (see table 28) show a high level of reliability of the data gotten from the sample of respondents.

Table 28. Facility's respondents' socio-demographic characteristics

Socio-demographic characteristics		Frequency (n = 35)	Percentage
Gender	Male	35	100
	Female	0	0
Nationality	Saudi Arabia	9	23.53
	Jordan	3	8.82
	Canada	3	8.82
	USA	2	5.88
	Egypt	2	5.88
	Sudanese	2	5.88
	Algeria	2	5.88
	Pakistan	2	5.88
	Not available	10	29.41
Age	30 - 40	1	2.94
	40 - 50	9	23.53
	50 - 60	20	58.82
	➢ 60	2	5.88
	N/A	3	8.82
Occupancy Profile	With more number of adults	23	67.65

	With more number of children	10	29.41
	N/A	2	2.94
Length of residency	6 – 12 months	6	14.71
	> 12 months	29	85.29
Time spent indoors/day	7 – 12 hours	12	35.29
	> 12 hours	23	64.71

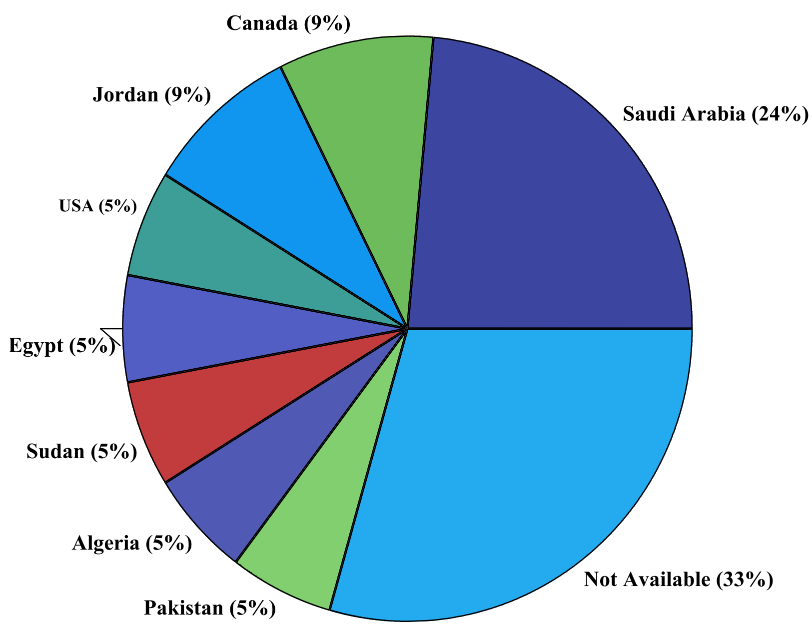


Figure 24. Respondents cultural profile according to the nationalities

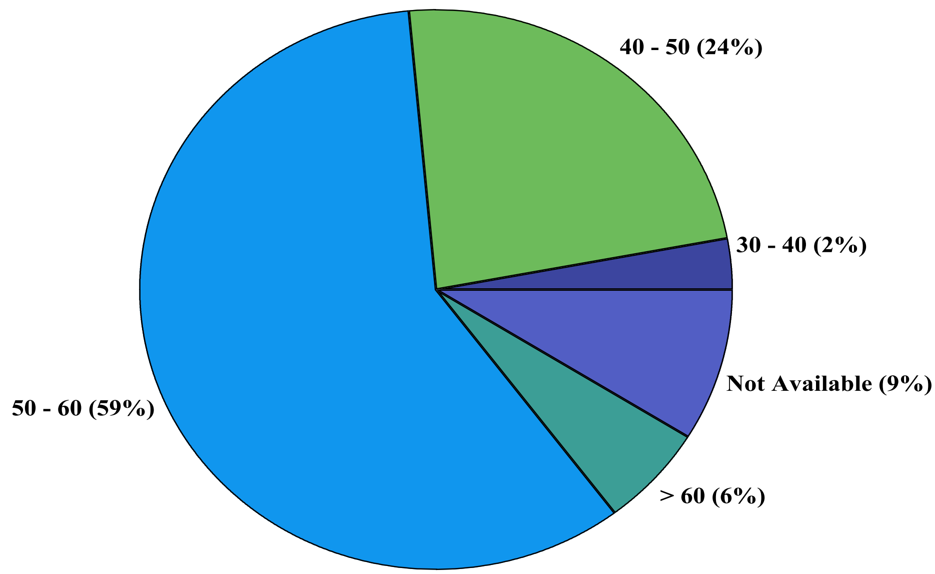


Figure 25. Respondent profile according to age

4.2.1 Building Performance Elements

In this section we discuss the results of multiple techniques employed. These include walkthroughs, objective measurements (instruments), subjective measurements (questionnaires) and focus group-meetings as presented in figure 6. The results are discussed under the headings of the eleven (11) performance elements with the exception of 'health' which was removed from the occupants' questionnaire survey after the professional survey was carried out for questionnaire validity. The values for 'Relative Importance Index (RII)' and the 'Mean Satisfaction Index (MSI)' are presented in tables, and have been calculated according to the methodology presented in section 3.6.2 and 3.6.3.5 respectively.

4.2.1.1 Thermal Comfort

A number of issues where identified for this performance element. Table 29 presents the descriptive statistics for this element. All ten indicators identified to influence occupants' perception of thermal comfort are presented. From the table it is observed that respondents are satisfied with all indicators except two: 'indoor temperature shifts' and the 'control of thermostat' which have MSIs of 2.84 and 2.67 respectively. The overall satisfaction with 'thermal comfort' is satisfactory with an MSI of 3.68 and standard deviation of 0.73, a standard deviation 0.73 means that occupants' perception is close to the mean score. The standard deviations for all indicators range between a region of 1.2 and 1.6 which means there is a potential for significant deviation of occupants perception from the mean values calculated.

Table 29. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for thermal comfort

Code No.	1.0 Thermal Comfort	Descriptive Statistics			
		RII	N	MSI	SD
1.1	Indoor Temperature in winter	3.67	35	3.94	1.20
1.2	Indoor Temperature in summer	4.00	35	3.38	1.30
1.3	Indoor Temperature shifts (stability)	3.67	34	2.84	1.46
1.4	Indoor Humidity	3.33	35	3.85	1.16
1.5	Air movement	4.33	35	3.15	1.39
1.6	Incoming sun	3.67	35	4.03	1.06
1.7	Drafts from windows/vents	4.00	35	3.41	1.05
1.8	Location/Accessibility of thermostat	3.33	35	3.24	1.54

1.9	Control of thermostat	3.67	34	2.67	1.57
1.10	Overall Satisfaction with thermal comfort	4.50	35	3.68	0.73

A plot of the Importance-Satisfaction Analysis matrix described in section 3.6.3.5 helps to identify critical areas to capitalize on or improve. The Importance –Satisfaction Analysis matrix for all indicators in the technical category is presented in figure 26. All indicators for 'thermal comfort' fall within the strengths region, except 1.3 'indoor temperature shifts' and 1.9 'control of thermostats' which falls in the region 'priorities for improvement'. This means that all indicators for thermal comfort should be maintained at their current level of performance or slightly increased, while 'control of thermostats' and 'indoor temperature shifts' requires some emphasis for its improvement.

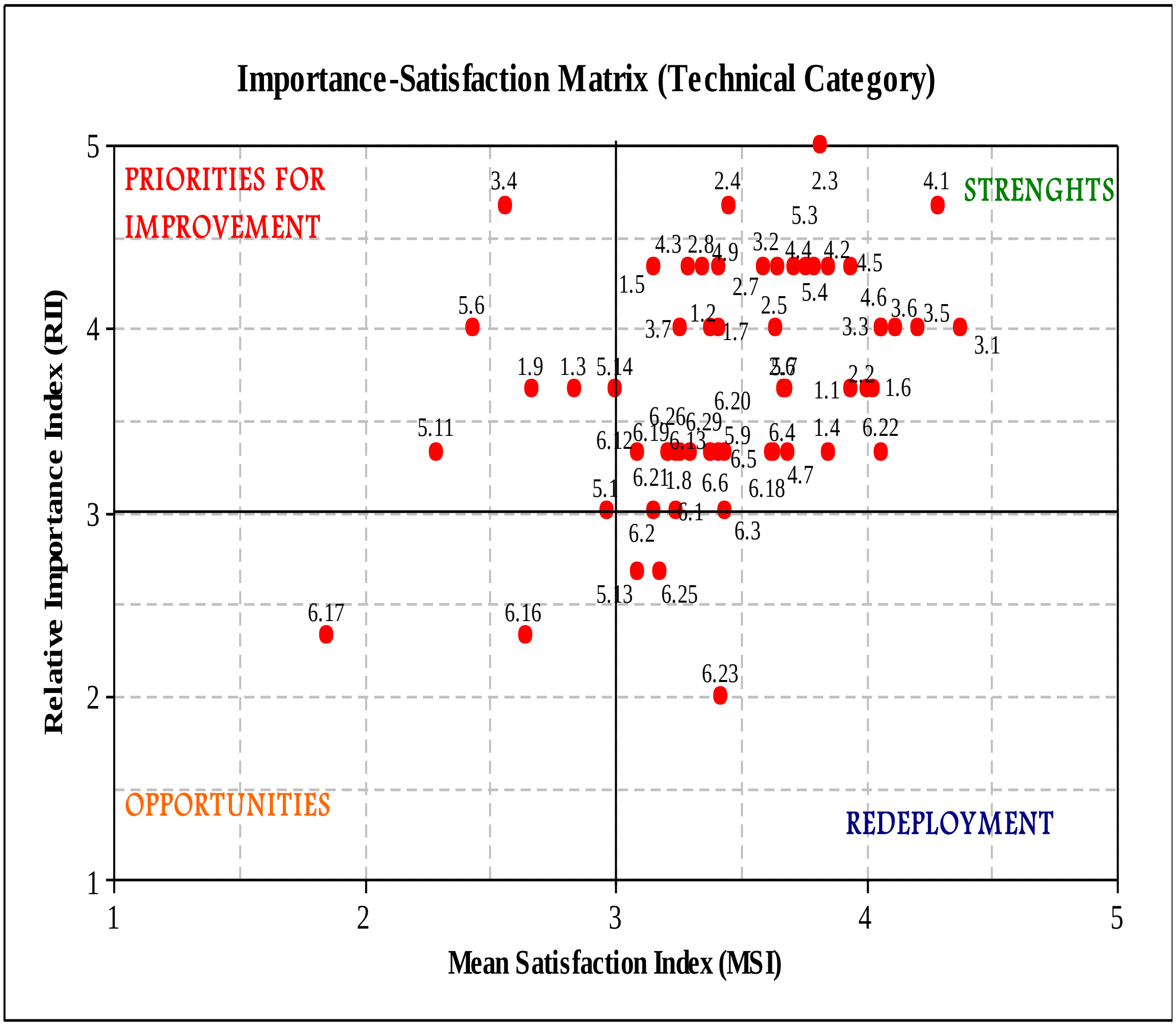


Figure 26. Importance-Satisfaction (IS) Analysis matrix for elements in the technical category (i.e. thermal comfort, indoor air quality, acoustic comfort, visual comfort, safety and security, management and maintenance)

The results of the questionnaire are also corroborated with open-ended feed-back from occupants (see appendix L) and a list of problems compiled by residents of the housing estate (see appendix D). Common themes are found such as: 'control and location of thermostats', 'strong air flows' and 'indoor temperature shifts/unevenness'. This is at par with the observations made with the questionnaire survey and measurements made with instruments which gave 20.5^oC for air temperature, 65% relative humidity and 3.5m/s air movement. Thus the measured temperature was below (22-27^oC) specified by ASHRAE standard 55, thermal environmental conditions for human occupancy.

4.2.1.2 Indoor Air Quality (IAQ)

Seven indicators were used to assess IAQ as a performance element. The descriptive statistics for these indicators are presented in table 30. It is observed from this table that all indicators fall within the range of 3 – 4 (neutral to satisfied), which means all occupants have a perception above average and close to satisfaction. The standard deviations also lie within the range of 0.99 to 1.2 showing a potential deviation from the mean values. The overall satisfaction (MSI) with IAQ is 3.62 with a standard deviation (SD) of 1.01 which shows satisfaction. This is further supported by the Importance-Satisfaction Analysis matrix in figure 26, with all indicators falling in the 'strengths' region, and thus requires that it should be monitored or slightly improved. A measure of Carbon dioxide (CO_2), Carbon Oxide (CO) and particles at both sides of all exits gave insignificant values since the building where these measurements were carried out was already vacated.

Though the questionnaire results and physical measurements are satisfactory, open-ended responses by occupants indicate a concern for dust coming from HVAC units, vents, and gaps around exit doors. The recorded level of the relative humidity was above the recommended rage stipulated by ASHRAE 62.1, 2004. If this value exceeds 70% for extended periods, it will promote the growth of some forms of mould and fungi.

Table 30. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for indoor air quality

Code No.	2.0 Indoor Air Quality	Descriptive Statistics			
		RII	N	MSI	SD
2.3	Adequacy of natural ventilation	5.00	35	3.82	1.03
2.4	Adequacy of mechanical ventilation	4.67	34	3.45	1.21
2.5	Air freshness in summer	4.00	34	3.64	1.03
2.6	Air freshness in winter	3.67	35	3.67	0.94
2.7	Odour/Air pollution	4.33	35	3.59	0.99
2.8	Air Flow	4.33	32	3.35	1.17
2.9	Overall satisfaction with indoor air quality	4.33	35	3.62	1.01

4.2.1.3 Acoustic Comfort

Acoustic comfort has been evaluated subjectively based on eight (8) performance indicators. The descriptive statistics which includes the mean satisfaction index (MSI), relative importance index (RII) and standard deviation (SD) is presented in table 31. The results show that 'noise from neighbours', 'noise from vehicles outside', 'noise from lighting fixtures' and 'other noise outside the building' were perceived by the occupants as satisfactory. 'Noise for air/HVAC system' was however rated as dissatisfied with an MSI of 2.56 below the average mark of 3.00. This result is corroborated with objective measurements of noise in all living spaces, a maximum value of 70.5dB was recorded in the kitchen, see table 33 for results of the noise measurements. The minimum measured value of 50dBA in two of the bedrooms exceeds the require 35 – 45 dBA specified for private residential buildings. The source of noise is identified as the vents in washrooms facilities.

This result is also supported by open-ended feed-back from occupants (see appendix L) and a list of problems compiled by residents of the housing estate (see appendix D). The HVAC system is identified as an extra source of noise, voices can be heard easily across rooms and echoes from the TV and radio are also present. Referring to figure 26, item 3.4 'Noise from air/HVAC system' fall in the 'priorities for improvement region' showing an emphasised need for improvement in this regard.

Table 31. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for acoustic comfort

Code No.	3.0 Acoustic Comfort	Descriptive Statistics			
		RII	N	MSI	SD
3.1	Noise from neighbours	4.00	35	4.38	1.04
3.2	Noise from people between rooms	4.33	35	3.65	1.43
3.3	Noise from vehicles outside	4.00	35	4.06	1.01
3.4	Noise from air/HVAC system	4.67	35	2.56	1.21
3.5	Noise from lighting fixtures	4.00	35	4.21	0.98
3.6	Other noise from outside the building	4.00	35	4.12	0.98
3.7	Control over noise	4.00	35	3.26	1.31
3.8	Overall satisfaction with noise	4.00	34	3.69	1.08

4.2.1.4 Visual Comfort

Ten (10) performance indicators where used to evaluate visual comfort as presented in table 32. The table also shows the descriptive statistics of the questionnaire survey results. The results show that the occupants are satisfied with the visual environment of their residences. 'Overall visual quality during the day' has an MSI of 4.15 which is above the mark for satisfaction. Lighting levels where measured for a combination of natural and artificial lighting to be as high as 430 Lux in living rooms, 250 Lux in the kitchen, 450 Lux in the family dining and 99 Lux in one of the bedrooms which is adjacent to a neighbouring building and thus has a reduced amount of natural light. Without the natural lighting low values were recorded as presented in table 33.

Table 32. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for visual comfort

Code No.	4.0 Visual Comfort	Descriptive Statistics			
		RII	N	MSI	SD
4.1	Amount of daylight (natural lighting)	4.67	35	4.29	0.97
4.2	Illumination level/How bright are the lights (artificial lighting) in the living room	4.33	35	3.85	1.08
4.3	Illumination level/How bright are the lights (artificial lighting) in the bedrooms	4.33	35	3.29	1.29
4.4	Control/Use of Electric lighting	4.33	35	3.71	1.12
4.5	Control of day lighting	4.33	35	3.94	0.81
4.6	Glare from lights	4.00	35	4.06	0.74

4.7	Exterior lighting levels in the night	3.33	33	3.69	1.12
4.9	View to outside	4.33	35	3.41	1.31
4.10	Overall visual quality in the house during the day	3.33	35	4.15	0.78
4.11	Overall visual quality in the house in the night	3.67	35	3.97	0.90

Table 33. Results of physical measurements for sound levels and light in living spaces

Living Space	Sound Level (dBA) Recommended: 35-45. Department of Defence	Light (Lux) Recommended: 200-500Lux for large size visual tasks; and 500-1000Lux for small size visual task. IESNA
Family living room	61.5	200 – OK
Guest washroom and toilet	67.3	240 – OK
Family dinning	62.5	256.7 – OK
Kitchen	70.5	150 – NOT OK
Study room	57	100 – NOT OK
Master bedroom	54	276.7 – OK
Master bedroom T/B	58	260 – OK
Bedroom 1&2	50	75 – NOT OK
Bedroom 1&2 Shared T/B	55	255 – OK
Bedroom 3	50	55 – NOT OK
Bedroom 3 T/B	60.5	250 – OK

Maid's Bedroom	57	230 – OK
Maids Bedroom T/B	62.7	280 – OK

Allowable lighting levels as per the IESNA standards presented in table 10 is 200 – 500 Lux for living areas where visual tasks of high contrast or large size like the kitchens and living rooms. And 500 – 1000 Lux for visual tasks of medium contrast or small size like the study. Thus the measured values presented in table 33 shows that the kitchen, the study room, and the bedrooms on the first floor except the master's bedroom and maid's bedroom all have lighting levels below the accepted standard. This is also supported by open-ended feed-back from occupants (see appendix L) and a list of problems compiled by residents of the housing estate (see appendix D). Occupants have identified the need for more lights in the bedrooms mentioned previously and the front yard at the building's main entrance. This type of feed-back gives a holistic view of the performance element which might not be mapped accurately with the questionnaire tool alone.

4.2.1.5 Safety and Security

This performance element was evaluated with thirteen (13) performance indicators as presented in table 34. The table also shows the descriptive statistics of the questionnaire survey results. The results show that the occupants are satisfied with the ease to exit the building in case of an emergency. The MSIs for 'security system of your house', 'quality and perception of fire safety systems in the building', 'quality of provided speed bumps' were just a little lesser than 3.0 the neutral mark. High standard deviations of 1.45 indicate potential dissatisfaction. Closer to dissatisfaction are 'anti-crime measure', and 'enforcement of maximum speed limit rules' with MSIs of 2.43 and 2.29 respectively. Referring to figure 26, performance indicators with code numbers 5.6 'anti-crime measure' and 5.11 'enforcement of maximum speed limit rules' fall in the 'priorities for improvement' region implying an emphasised need for improvement in this regard. Performance indicator 5.13 'quality of landscaping in facilitating safe driving' falls in the 'redeployment region' which means less emphasis can be placed on this item.

The open-ended feed-back from occupants (see appendix L) and list of problems compiled by residents of the housing estate (see appendix D) also support these observations. Occupants have expressed concern with the control of speed around the estate, and the safety provisions provided. Also the provision of safety systems like fire alarms, surveillance camera and access to the buildings electric main switch board for emergency.

Table 34. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for safety and security

Code No.	5.0 Safety and Security	Descriptive Statistics			
		RII	N	MSI	SD
5.1	Security system of your house	3.00	35	2.97	1.49
5.2	Quality and perception of fire safety systems in the building	3.50	34	2.79	1.45
5.3	Ease to identify Emergency/Escape route	4.33	35	3.76	1.18
5.4	Ease of exiting the building in cases of fire emergencies	4.33	35	3.79	1.23
5.6	Anti-crime measures	4.00	31	2.43	1.36

5.7	Level of security in the neighbourhood	3.67	35	3.68	1.07
5.8	Level of safety measures in children playground areas	4.00	32	2.71	1.23
5.9	Level of safety measures in streets and walkways	3.33	35	3.38	1.05
5.11	Enforcement of maximum speed limit rules	3.33	35	2.29	1.24
5.12	Quality of provided speed bumps	3.00	34	2.85	1.18
5.13	Quality of landscape design in facilitating safe driving	2.67	35	3.09	1.08
5.14	Protection against insects and dangerous animals	3.67	35	3.00	1.16
5.15	Overall satisfaction with safety and security	4.00	35	3.06	1.07

4.2.1.6 Maintenance and Management

Twenty (20) performance indicators where used to evaluate maintenance and management as presented in table 35. All performance indicators are rated as satisfactory being above average except for the 'maintenance of paving around the building' and 'communal greenery' with MSIs of 2.64 and 1.85 respectively. Maintenance of 'heating and water systems' is slightly above average MSI of 3.09. The Importance –Satisfaction Analysis matrix for all indicators in the technical category presented in figure 26 show that performance indicator 6.16 'paving around the building' and 6.17 'communal greenery' fall within the region of opportunities which means low satisfaction and importance levels. Thus it does not contribute significantly to the overall satisfaction for management and maintenance. Performance indicator 6.2 'maintenance of hinges and locks of windows and external doors', 6.3 'maintenance of kitchens', 6.23 'maintenance team keep residents informed', 6.25 'frequency of maintenance' fall within the 'redeploy' region implying that these issues do not need much emphasis.

The results from the questionnaire survey are supported by open-ended feed-back from the respondents. Common issues identified by respondents include the 'maintenance of water, heating and ventilation systems' and also 'late response of maintenance management'.

Table 35. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for management and maintenance

Code No.	6.0 Management and Maintenance	Descriptive Statistics			
		RII	N	MSI	SD
Satisfaction with maintenance of building components					
6.1	Exterior paintwork	3.00	35	3.24	1.26
6.2	Hinges and locks of windows and external doors	3.00	35	3.15	1.11
6.3	Kitchens	3.00	35	3.44	1.11
6.4	Drains	3.33	35	3.62	1.16
6.5	Toilets	3.33	35	3.44	1.13
6.6	Bathrooms	3.33	35	3.41	1.10
Maintenance of installations					
6.12	Heating and water systems	3.33	35	3.09	1.38
6.13	Ventilation systems	3.33	35	3.26	1.16

Maintenance of surrounding grounds:					
6.16	Paving around the building	2.33	34	2.64	1.27
6.17	Communal greenery	2.33	34	1.85	1.23
Management issues:					
6.18	Treatment of residents	3.33	33	3.63	1.09
6.19	Handling of residents' complaints	3.33	35	3.24	1.21
6.20	Management response to necessary repairs	3.33	35	3.38	1.05
6.21	Management team's resources to do the job	3.33	35	3.21	1.12
6.22	Ease to contact maintenance department	3.33	35	4.06	0.92
6.23	Maintenance team keep residents informed	2.00	34	3.42	0.97
6.25	Frequency of house maintenance	2.67	35	3.18	0.87
6.26	Speed and efficiency of maintenance services for indoor facilities	3.33	35	3.21	1.18
Others					
6.29	Level of Deterioration in building	3.33	31	3.30	1.09
6.30	Overall satisfaction with management and maintenance of facilities in the housing estate	3.33	32	3.52	0.93

4.2.1.7 Layout, Furniture and Spatial Comfort

Thirty seven (37) performance indicators are presented in table 36 for this performance element. A descriptive statistics of the results show that all performance indicators were above the average satisfactory mark 3.0 except 'space for landscaping', 'size of maid's bedroom' and 'quality of carpentry work for maid's bedroom' having MSIs of 2.85, 2.18, 2.97 respectively. The Importance –Satisfaction Analysis matrix for all indicators in the functional category presented in figure 27 shows that performance indicator 8.4 'space for landscaping' is in the region to be considered as a priority for improvement. 8.15 'size of maids bedroom' and 8.34 'quality of carpentry in maid's bedroom' falls in the 'opportunities' region implying that there is no need for extra emphasis on these indicators. 8.21 'size of dining room', 8.22 'size of family living room', 8.23 'size of personal storage/capacity of wardrobe', 8.31 'quality of carpentry in dining room' are in the region labelled 'deployment', this implies that this indicators should be maintained in their current state or slightly improved.

Further to the results derived from the questionnaire survey, the open-ended feed-back from occupants (see appendix L) and list of problems compiled by residents of the housing estate (see appendix D) provide additional information. A number of occupants expressed dissatisfaction with the size of the maid's room and the size of toilet and bath (T/B) in the master's bedroom. Also concerns about the poor quality of carpentry work and air infiltration bringing into the building dust and sand around exit doors which expand and contrast were raised.

Table 36. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for Layout, Furniture and Spatial Comfort

Code No.	8.0 Layout, Furniture and Spatial Comfort	Descriptive Statistics			
		RII	N	MSI	SD
8.1	Type of House	3.50	35	4.29	0.91
8.2	Plot size	4.33	34	4.33	0.92
8.3	Adequacy of circulation routes around the building	3.50	35	4.21	0.91
8.4	Space for landscaping	4.0	35	2.85	1.46
8.5	No of rooms in your house	3.33	35	4.18	1.11
8.6	Location of rooms in your house	3.67	35	4.21	1.09
8.7	Suitability of the location of bathrooms relative to guest reception area	4.33	35	3.82	1.45
8.8	Room performance/Layout of the rooms	4.00	35	3.97	0.99
8.9	Functionality in design	4.67	35	4.06	0.92
8.10	Vertical circulation within building	2.33	34	3.91	0.95
8.11	Horizontal circulation within building	2.67	34	3.94	0.93
8.12	Scale and proportion of the floor plan	3.67	34	3.88	1.11
8.13	Ceiling height (head room)	3.67	34	4.12	1.05
Size of individual spaces					
8.14	Master Bedroom	4.00	35	4.47	0.93
8.15	Maid's Bedroom	2.33	35	2.18	1.34
8.16	Bedroom 1	3.00	35	4.15	0.96

8.17	Bedroom 2	2.33	34	4.06	1.03
8.18	Bedroom 3 (if applicable)	3.00	21	4.00	1.05
8.19	Reception	3.33	35	4.32	0.91
8.20	Study room	2.67	35	3.97	1.19
8.21	Dining room	2.67	35	4.26	0.93
8.22	Family Living room	2.67	35	4.18	1.17
8.23	Personal storage/Capacity of Wardrobe	2.00	34	3.61	1.52
8.24	Overall satisfaction with amount of Space/Size of the rooms	3.33	35	4.18	0.94
Quality of carpentry work for					
8.25	Doors and windows	3.67	35	3.38	1.05
8.26	Kitchen	3.00	33	3.25	1.16
8.27	Bathroom cabinets	3.00	35	3.26	0.99
8.28	Closets (wardrobe)	3.00	35	3.35	1.18
8.29	Reception	3.33	34	3.88	0.74
8.30	Study room	3.00	33	3.63	1.07
8.31	Family dining room	3.00	34	3.88	0.96
8.32	Family living room	3.33	33	3.88	0.94
8.33	Master Bedroom	3.67	34	3.79	1.08
8.34	Maid's Bedroom	3.00	35	2.97	1.31
8.35	Bedroom 1	3.00	35	3.88	0.98

8.36	Bedroom 2	3.00	35	3.88	0.98
8.37	Bedroom 3 (if applicable)	2.67	20	3.84	0.96

4.2.1.8 Housing Support Services

Thirty five (35) indicators that are used to evaluate this element are presented in table 37. The descriptive statistics for these indicators are also presented. It is observed from this table that all indicators are above the average level of satisfaction except, 'the type of electrical outlets used', 'effectiveness of doors in preventing dust', 'storm water drainage system', 'accessibility to disabled and aged people', 'open spaces, parks and reserves', 'availability and children's play-ground and ladies centre', 'internet/television connection points' with MSIs of 2.97, 2.64, 2.97, 2.45, 2.69, 2.06 and 2.68 respectively.

Open-ended feed-back from occupants (see appendix L) and list of problems compiled by residents of the housing estate (see appendix D) provide additional feed-back highlighting over elevated bath-tubs in the masters bedroom, the need for a shower facility on the ground floor, high salinity of water for domestic use, improper location of toilet paper dispenser, small size of washroom facility in master's bedroom, and the need for children playground areas.

Table 37. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for Housing Support Services

Code No.	9.0 Housing Support Services	Descriptive Statistics			
		RII	N	MSI	SD
9.1	Stability of power	4.67	35	4.35	0.92
9.2	Availability and quality of drinking water	4.33	34	3.27	1.23
9.3	Adequacy of power sockets	3.67	35	3.65	1.15
9.4	Flexibility of IT/TV connection points	3.33	35	3.53	1.21
9.5	The type of electrical outlets used	3.33	35	2.97	1.22
9.6	The number and position of electrical sockets	3.33	35	3.85	1.05
9.7	The operation of electrical fittings	3.33	34	3.67	1.05
9.8	Operation of Windows	2.00	34	3.79	0.96
9.9	Windows for kitchen or bathroom	2.67	35	3.94	0.92
9.10	Effectiveness of windows in preventing dust	3.33	35	3.50	1.33
9.11	Operation of Doors	3.33	35	3.53	1.19
9.12	Operation of Door bell and opening system	2.67	34	3.27	1.18
9.13	Effectiveness of doors in preventing dust	3.33	34	2.64	1.32
9.14	The functioning of plumbing fittings	3.67	34	3.24	1.09
9.15	Number of washroom facilities (T/B)/Adequacy of washroom facilities	3.33	33	3.69	0.97
9.16	Size of T/B in Master Bedroom	3.67	33	3.53	1.46
9.17	Size of T/B in Maid's Bedroom	2.33	33	3.16	1.39

9.18	Size of T/B in Bedroom 1	3.00	33	3.72	1.17
9.19	Size of T/B in Bedroom 2	3.00	32	3.71	1.19
9.20	Size of T/B in Bedroom 3 (if applicable)	3.00	18	3.65	1.32
9.21	Storm-water drainage system	3.67	31	2.97	1.27
9.22	Refuse disposal system/ Cleanliness and trash removal	4.00	35	3.68	1.09
9.23	Efficiency of insect spray services	3.00	33	3.13	1.34
9.24	Accessibility to disabled and aged people	3.67	32	2.45	1.21
9.25	Street lightning	3.67	33	3.76	1.09
9.26	Open spaces, parks and reserves	3.67	33	2.69	1.28
9.27	Availability and children's play-ground and ladies centre	3.33	35	2.06	1.13
9.28	Availability of good roads and sidewalks	3.67	35	3.71	1.09
9.29	Design of on-site car parking space is efficient (roof, space arrangement)	3.67	34	3.27	1.33
9.30	Adequacy of off-street parking	3.67	35	3.53	1.11
9.31	Adequacy of artificial lighting levels in the car parking space	3.67	35	3.88	0.95
Capacity and Efficiency of utility systems					
9.33	Electrical	4.33	34	4.03	0.81
9.34	Water supply	3.67	35	3.91	0.87
9.36	Refrigerator	3.33	35	3.62	1.18
9.37	Stove	3.33	35	4.00	1.02

9.38	Oven	3.33	34	4.00	0.97
9.39	Kitchen exhaust vent	4.00	35	3.71	1.06
9.40	Washing machine	3.33	35	4.03	0.76
9.42	Internet/Television connection points	3.00	35	2.68	1.34

The Importance-Satisfaction Analysis matrix presented in figure 27, with all indicators falling in the 'strengths' region, and thus requires that it should be monitored or slightly improved. This is to the exception of performance indicators like: 'operation of windows'; 'size of T/B in maid's bedroom'; and 'operation of door bell and opening system' fall in the 'redeployment' region and thus not in need of extra emphasis. 'Internet/television connection points', 'availability and children's play-ground and ladies centre', 'accessibility to disabled and aged people', 'open spaces, parks and reserves', 'storm-water drainage system' and 'type of electrical outlets used' all fall in the region requiring improvement with some level of priority (figure 27).

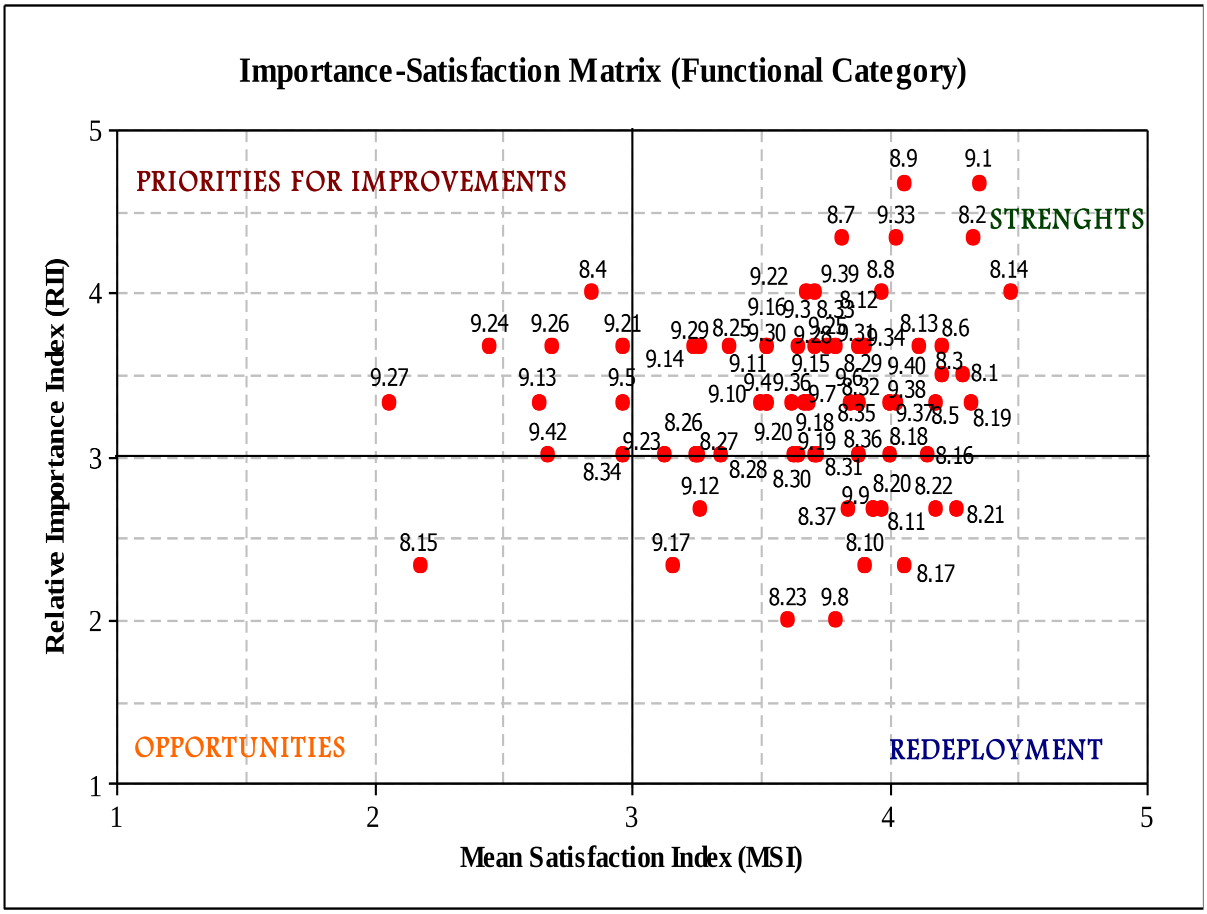


Figure 27. Importance-Satisfaction (IS) Analysis matrix for elements in the functional category (i.e. layout, furniture ans spatial comfort, and housing support services)

4.2.1.9 Privacy and Territoriality

This performance element was evaluated with seven (7) performance indicators as presented in table 38. The table also shows the descriptive statistics of the questionnaire survey results. All performance indicators are above the average satisfaction. The Importance –Satisfaction Analysis matrix for all indicators in the behavioural category presented in figure 28 shows that all indicators fall in the strengths region except 10.6 'density of population within the estate' which falls in the 'redeployment' region implying the need to avoid or reduce any extra emphasis placed on this performance indicator.

The results of the open-ended feed-back from occupants (see appendix L) and list of problems compiled by residents of the housing estate (see appendix D) show that occupants expressed great concern for privacy due to close proximity of neighbouring buildings.

Table 38. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for privacy and territoriality

Code No.	10.0 Privacy and Territoriality	Descriptive Statistics			
		RII	N	MSI	SD
10.1	The level of privacy within spaces in your house	4.33	35	3.91	1.06
10.2	Privacy from your neighbours	3.67	35	3.74	1.39
10.3	Distance of your building from your side boundary fence	3.67	33	3.72	1.25
10.4	Distance of your building from the rear boundary fence	3.33	33	3.72	1.30
10.5	Building setback	3.67	29	3.86	1.01
10.6	Density of Population within the estate	2.50	34	4.00	0.90
10.7	Overall satisfaction with privacy and territoriality	3.67	34	3.73	1.09

4.2.1.10 Location

Twenty (20) indicators that are used to evaluate this element are presented in table 39. The descriptive statistics for these indicators are also presented. Very high occupant satisfaction ratings where observed in this category. Occupants were most satisfied with the closeness of their residential compounds to their 'work place' which is expected for a campus residential facility. 'Size of estate', 'appropriateness of location for residential buildings' and 'places of worship' have MSIs above the mark for satisfaction 4.0. The Importance –Satisfaction Analysis matrix for all indicators in the behavioural category presented in figure 28 shows that all indicators fall in the strengths region except 11.6 'proximity/nearness of your house to friend', 11.14 ''proximity/nearness of your house to restaurants', 11.15 'proximity/nearness of your house to library', 11.16 'extent of social relations amongst neighbours' which falls in the 'redeployment' region implying that these indicators are below average importance and above the average level of satisfaction and thus not in need of any further emphasis on improvement. Any extra resources available for this can be redeployed to other performance indicators.

Table 39. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for location

Code No.	11.0 Location	Descriptive Statistics			
		RII	N	MSI	SD
11.1	Size of estate	3.33	35	4.21	0.88
11.2	Appropriateness of location for residential buildings	3.67	35	4.29	0.87
11.3	Location of House in estate	3.67	34	4.27	0.84
Proximity/Nearness of your house to:					
11.4	Places of worship	4.00	33	4.25	0.92
11.5	Children's schools	4.00	32	4.13	0.92
11.6	Friends	2.33	33	4.09	0.89
11.7	Market and shopping centres	3.33	32	3.81	1.08
11.8	Recreational/Sport facilities	3.00	31	3.50	1.19
11.9	Workplace	4.00	33	4.31	0.89
11.10	Medical facilities	4.00	32	4.00	1.18
11.14	Restaurants	2.33	30	3.10	1.26

11.15	Library	2.67	29	3.43	1.29
Others					
11.16	Extent of social relation among neighbours	2.33	32	3.34	1.12
11.19	Level of crime and anti-social activities in the housing estate where you live	3.67	30	3.83	0.91
11.20	Suitability to natural way of life	3.67	30	3.70	0.88
11.21	Rule and regulations of housing estate	3.33	29	3.76	0.83

4.2.1.11 Appearance

This performance element was evaluated with fourteen (14) performance indicators as presented in table 40. The table also shows the descriptive statistics of the questionnaire survey results. All performance indicators are above the average satisfaction, except the 'quality of materials used in floors', 'green areas (vegetation)', 'landscaping of neighbourhood', and 'general aesthetic appearance' with MSIs of 2.97, 1.94, 2.21 and 2.68 respectively. The 'quality of materials used for paints' has an MSI of 3.06 just above the average mark of 3.0. These results are further expounded in the open-ended feed-back from occupants (see appendix L) and list of problems compiled by residents of the housing estate (see appendix D).

Occupants the expressed dis-satisfaction with the paints, tiles, stains on the walls, and corrosion of fixtures in the washrooms, landscaping of the estate and general appearance. A general perception of low quality and dissatisfaction is inherent amongst the occupants which are supported by the results of the survey. The rating for 'general aesthetic appearance' is 2.68 below the average mark of 3.0 and a standard deviation SD of 1.17 which implies that none of the occupants is 'very dissatisfied' however majority of the occupants are dissatisfied with the 'general aesthetic appearance'.

Table 40. Descriptive Statistics for Occupants' residential satisfaction index (RII) and Mean Satisfaction Index (MSI) for appearance

Code No.	12.0 Appearance	Descriptive Statistics			
		RII	N	MSI	SD
Design and quality of:					
12.1	Toilets	2.67	34	3.38	1.10
12.2	Kitchen	3.67	34	3.68	1.15
12.3	Bathrooms	3.00	33	3.21	1.24
Quality of materials used in:					
12.4	Floors	4.00	34	2.97	1.38
12.5	Ceilings	4.00	34	3.50	1.161
12.6	Walls	4.00	34	3.44	1.21
12.7	Paints	4.00	34	3.06	1.35
Others:					
12.8	Colours used in exterior of the house	3.33	34	3.62	1.02
12.9	Colours used in interior of the house	3.67	34	3.53	1.02
12.11	Streets and foot paths design	2.67	33	3.42	1.03
12.12	Green areas (vegetation)	2.67	33	1.94	1.14
12.13	Landscaping of neighbourhood	3.00	33	2.21	1.27
12.14	General aesthetic appearance	3.67	31	2.68	1.17

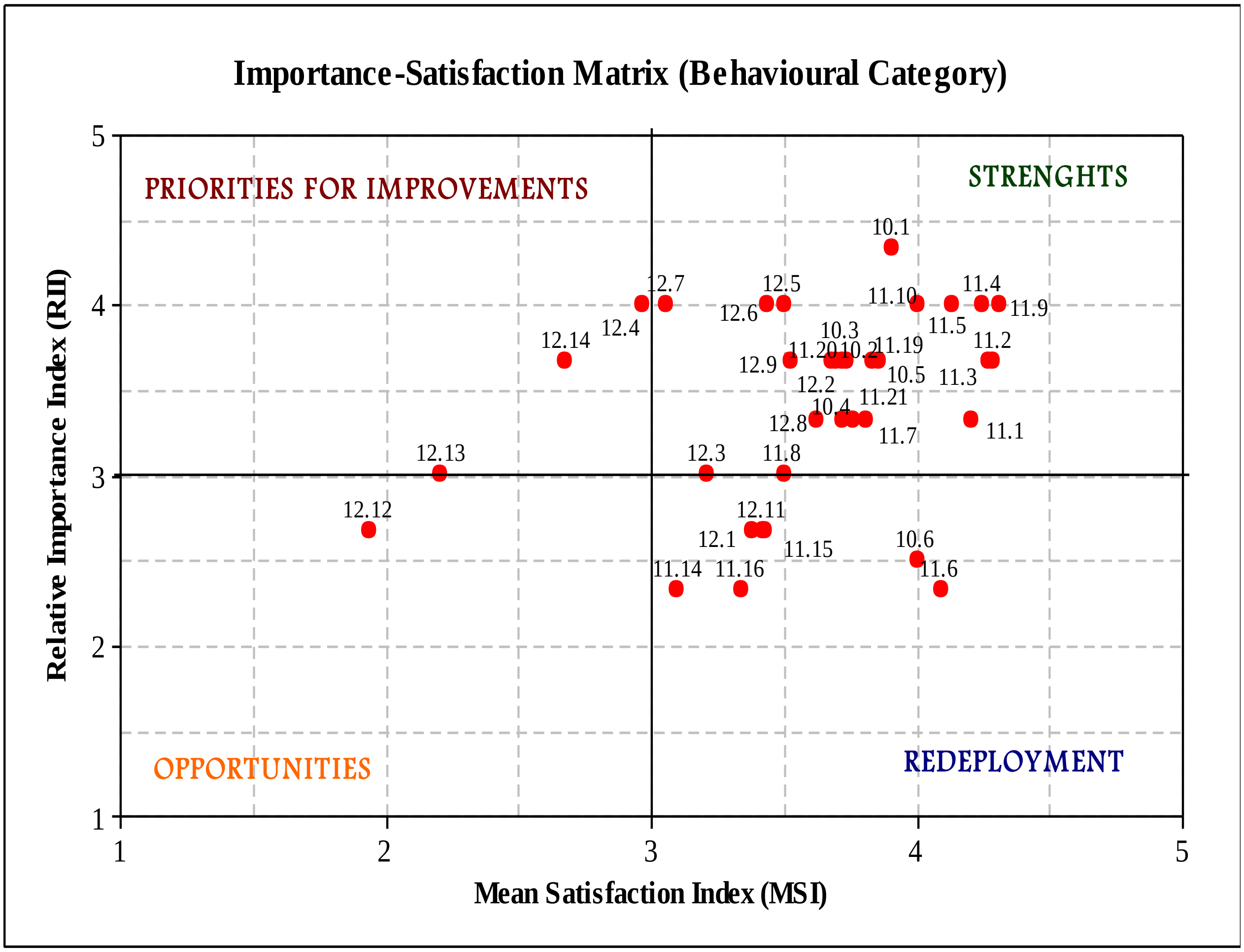


Figure 28. Importance-Satisfaction (IS) Analysis matrix for elements in the functional category (i.e. privacy and territoriality, location and appearance)

The Importance –Satisfaction Analysis matrix for all indicators in the behavioural category presented in figure 28 shows performance indicator 12.1 'design quality of toilets', 12.3 'design quality of bathrooms' and 12.11 'streets and foot paths design' fall within the 'redeployment' region suggesting the absence of a need for any extra emphasis on those indicators. While performance indicators 12.4 'quality of materials for floors', 12.7 'quality of materials used in paints', 12.13 'landscaping of neighbourhood', and 12.14 'general aesthetic appearance' are priorities for improvement. Performance indicators

12.12 'green areas (vegetation)' fall within the 'opportunities' region which implies below average importance as well as below average mean satisfaction index, thus improvements are needed without it being a priority.

4.2.2 Inferential Statistics

In this section we discuss the results of some inferential statistics carried out on the results of the questionnaire survey. These include two-sample T-tests of two occupancy groups and a multi-linear regression analysis of respondents overall satisfaction indices as explained in section 3.6.3.5.

Table 41. Respondents' Satisfaction Index (SIr) of the living environment

R1	53.89	R9	68.61	R17	61.12	R25	60.36	R33	62.14
R2	64.5	R10	62.28	R18	50.66	R26	58.72	R34	83.00
R3	61.67	R11	85.29	R19	72.02	R27	75.43	R35	65.00
R4	55.49	R12	79.22	R20	65.29	R28	60.43		
R5	85.22	R13	53.48	R21	68.23	R29	64.11		
R6	77.58	R14	67.65	R22	51.91	R30	73.87		
R7	55.09	R15	59.69	R23	64.34	R31	65.58		
R8	62.27	R16	52.17	R24	56.86	R32	70.76		

R_1, R_2, R_3, ... represent questionnaire survey respondents

The calculated values for the respondents' Satisfaction Index (SIr) of the living environment as explained in section 3.6.3.5 with equation 4 and is presented in table 41. A probability plot is also presented of respondents' Satisfaction Index (SIr) of the living environment presented in figure 29. The probability plot shows that the respondents overall satisfaction index is normally distributed with a 95% confidence interval. This means that all inferential statistics requiring normality of the data set can be conducted such as t-tests and regression analysis. The mean of the overall residential satisfaction in calculated to be 64.97 showing a moderate residential satisfaction according to Mohit et al., 2010 'regime of satisfaction'.

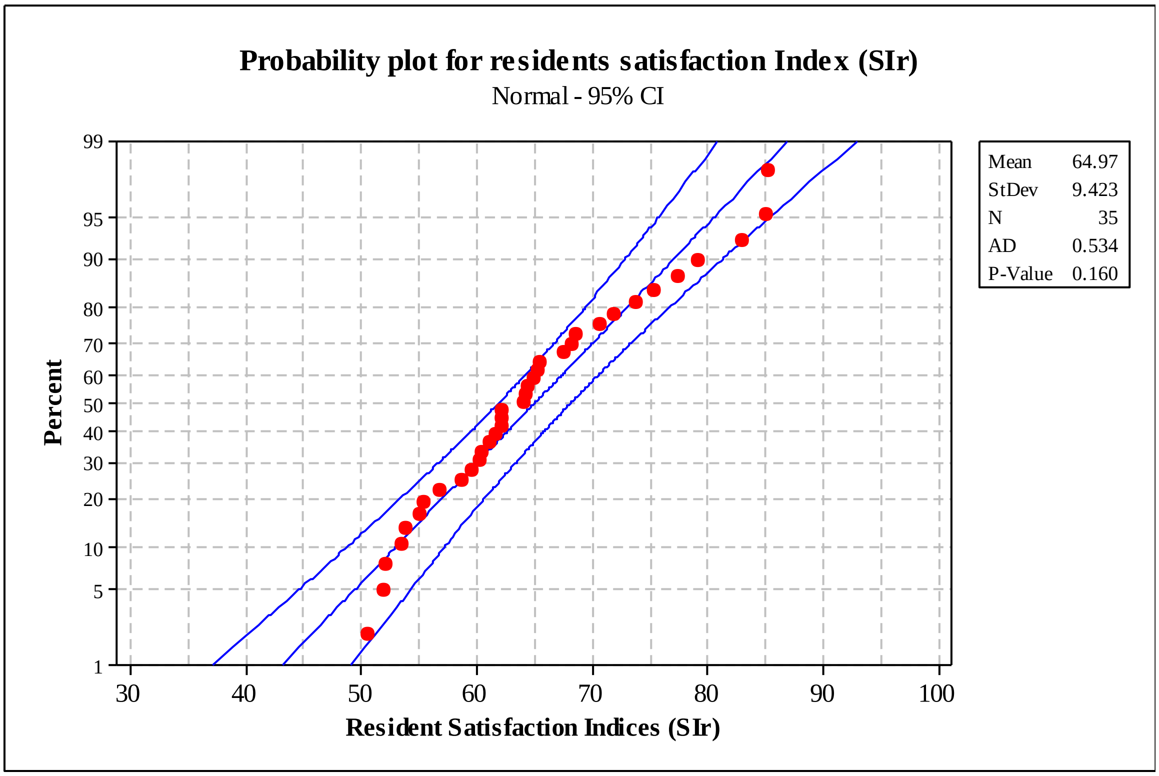


Figure 29. Probability plot for respondents' Satisfaction Index (SIr) of the living environment

4.2.2.1 Two-Sample T-Test

This test as explained in section 3.6.3.5 was conducted between two groups to test the null hypothesis that families with more children will not answer the questionnaire differently when compared to families with more adults. The null hypothesis is an assumption that the means of both groups are equal and thus occupancy profile is not a factor in determining respondents' satisfaction with the residential environment. The p-value from this test is 0.336 which is greater than 0.05 (or 5 percent) and thus there is no evidence for a difference in residential satisfaction between building occupants 'with more children' or 'more adults'. See table 42.

Table 42. Two-sample T for 'More Adults' vs 'More Children'

Groups	N	Mean	StDev	SE Mean
Houses with more adults	10	65.8	12.7	4.0
Houses with more children	10	70.37	7.06	2.2
Difference = mu (More Adults) - mu (More Children) Estimate for difference: -4.58 95% CI for difference: (-14.44; 5.28) T-Test of difference = 0 (vs not =): T-Value = -1.00 P-Value = 0.336 DF = 14				

N: Sample size StDev: Standard Deviation SE: Standard Error CI: Confidence Interval DF: Degrees of Freedom

4.2.2.2 Multi-Linear Regression Analysis

Multiple Linear Regression (MLR) analysis is explained in detail in section 3.6.3.5. Here we discuss the results of this test as presented in table 43. A linear model containing the best linear combination of 20 performance indicators for predicting overall residential satisfaction using stepwise method resulted in the selection of 10 predictor variables after 12 steps and a constant of 48.34. It is observed from the table that 1. 2 'indoor temperature in summer', 6.16 'Maintenance of paving around the building', 3.2 'noise from people between rooms', 12.4 'Quality of materials used in floors', 1.3 'indoor temperature shifts' are from the most significant factors contributing to the overall residential satisfaction of occupants. The adjusted R^2 value (91.56) of the model indicates that the performance indicators in table 43 are 91.56% responsible for changes in residential satisfaction.

Table 43. Regression analysis of residential satisfaction index with performance indicators

Constant: 48.34	Std error of estimate: 2.48	R-Sq: 95.53	R-Sq(adj): 91.56	
Code No.	Indicator	Co-efficient	T-value	P-value
1.2	Indoor Temperature in Summer	12.3	7.65	0.000
6.16	Maintenance of paving around the building	4.54	4.72	0.001
12.4	Quality of materials used in floors	2.01	2.56	0.027
3.2	Noise from people between rooms	1.35	1.58	0.142
1.3	Indoor temperature shifts (stability)	-8.9	-5.42	0.000
12.12	Green areas (vegetation)	-4.5	-3.93	0.003
12.7	Quality of paints	2.89	5.00	0.089
4.3	Illumination level/How bright are the lights (artificial lighting) in the bedrooms	-1.94	-2.73	0.023
3.4	Noise from air/HVAC system	1.53	1.79	0.107
5.11	Enforcement of maximum speed limit rules	-1.15	-1.60	0.144

4.3 Focus group meeting

The issues identified for a focus group meeting include: 'performance HVAC system'; 'lightning system'; 'size of maids bedroom'; 'size of washroom in masters bedroom'; 'availability of shower facility on the ground floor'; 'availability of parks and open spaces'; 'privacy'; and 'driver's lodge'. The results of the discussions about these issues are summarised as follows:

1. Performance of HVAC system: it was discovered that noise and control of the thermostat are the main issues with the HVAC system. The thermostat does not reflect the indoor air conditions of the various spaces within the thermal zone. It also cannot be set by occupants to the desired temperature preferred.
2. Lighting system: all participants of the focus group meeting agree that the amount of lightning in the bedroom is inadequate. And though they are able to supplement this with lamps, the lighting provided by the housing department should be upgraded to an acceptable standard.
3. Size of maid's bedroom: the small size of the maid's bedroom to some respondents was a non-issue due to the fact that they don’t have maids. However they agreed that for occupants with maids then it was necessary to increase the size of the maid's bedroom to accommodate some furniture including: a bed and wardrobe.
4. Size of washroom in master's bedroom: the issues identified in this regard include the height of the bath-tub and inadequate spacing between the facilities in the washroom. They agree that an increased size of the washroom will allow ease of use and also circulation. The height of the bath-tub is also identified as a priority due to occupants wives that may be pregnant or past middle age.
5. Availability of shower facility on the ground floor: all participants of the focus group meeting agree that one of the washroom facilities in the ground floor should be redesigned to include a shower facility. This they pointed was to serve guests

or occupants with limited mobility such as grand-parents or occupants with physical impairment.

6. Availability of parks and open spaces: it was noted that though parks and garden are required, it is not a matter of priority since other housing courts within the campus have such facilities which are easily accessible to all.
7. Privacy: this was identified as one of the major issues that all building occupants agree on. It was suggested that the design should be reviewed to take this issue into consideration.
8. The driver's lodge: this has been kept under lock and key which some of the occupants have expressed concern about. The focus group meeting participants note that some occupants might have privacy concerns if the drivers lodge was utilised while others are eager to use this facility for the convenience of their drivers.

4.4 Summary and Comparison of Results

The data derived from the five (5) evaluation methods including: walkthrough; review of existing documents; questionnaire survey; physical measurements and focused group meetings was analysed separately, and the results have been presented in previous sections. This section presents a summary and comparison of the observations made. Table 44 presents the key findings of each evaluation method according to the performance elements. The results derived from the observations were consistent with each other and they provided more qualitative information on the issues identified. There were no conflicts in the results obtained from each observation method. The focus group meetings also confirm some of the issues identified by the previous observation methods. In the table the last column 'remarks' presents the aggregate of the observation with numbering of each column in the table as a means of reference.

Table 44. Summary and Comparison of Results

Evaluation Methods	Performance Elements
	Thermal Comfort
Walkthrough (1)	Strong air flow from the HVAC unit was observed. Also the thermostat cannot be controlled at a desired temperature
Review of documents (2)	Complains of strong air flows and temperature shifts or unevenness. And poor performance of thermostats. Noise from HVAC system
Questionnaire Survey (3)	Dissatisfaction with 'Indoor Temperature Shifts' and 'Control of thermostats'
Physical Measurements (4)	Recorded values: 20.5°C for air temperature, 65% relative humidity and 3.5m/s air movement
Focus group meetings (5)	Noise from the HVAC system and control of thermostats are the major issues identified
Common issues identified from the evaluation methods above	Strong air flows (1,2,4), Control of thermostats (1,2,3,5) Temperature unevenness (2,3), Noise from HVAC system (2,3,5)
	Indoor Air Quality
Walkthrough (1)	Accumulation of dust at the exit doors
Review of documents (2)	Complaints of exit doors allowing the entrance of dusts due gaps
Questionnaire Survey (3)	All indications were above satisfaction
Physical Measurements (4)	No significant values since apartment was vacated 6 months before measurements
Focus group meetings (5)	Not discussed
Common issues identified from the evaluation methods above	Dust from exit doors (1,2)
	Visual Comfort
Walkthrough (1)	Low light levels in study and bedrooms was observed, lighting was improved when combined with natural

	lighting
Review of documents (2)	Complaints about light levels in the bedrooms front yard at the building's main entrance
Questionnaire Survey (3)	All indications were above satisfaction
Physical Measurements (4)	Recorded values below standard: 150Lux in the Kitchen, 100Lux in the study and 55Lux /75Lux in the bedrooms
Focus group meetings (5)	Amount of lighting in bedrooms is inadequate
Common issues identified from the evaluation methods above	Low lighting levels in study, bedrooms (1,2,4,5) Low lighting level at front yard (2)
	Acoustic Comfort
Walkthrough (1)	Disturbing noise observed in the washroom facilities and kitchen due to vents
Review of documents (2)	Complaints of noise from: HVAC system ; transfer of voices across rooms and echoes from the TV and radio
Questionnaire Survey (3)	Dissatisfaction with 'Noise for air/HVAC system'
Physical Measurements (4)	Recorded values above standard: 70.5dBA in the kitchen; and 50dBA in two of the bedrooms
Focus group meetings (5)	Not discussed
Common issues identified from the evaluation methods above	Noise from vents in washroom and kitchen (1,4), Noise from HVAC system (2,3), Noise transfer between rooms and echo (2)
	Security and Fire Safety
Walkthrough (1)	No Observations
Review of documents (2)	Complaints about the control of speed around the estate; provision of safety systems like fire alarms, surveillance camera and access to the buildings electric main switch board for emergency
Questionnaire Survey (3)	Dissatisfaction with 'security system', 'quality and perception of fire safety systems in the building', 'quality of provided speed bumps', 'anti-crime measure', and 'enforcement of maximum speed limit rules'
Physical Measurements (4)	No Observations
Focus group meetings (5)	Not discussed
Common issues identified from the evaluation methods above	Speed control around estate (2,3), Safety and Security systems (2,3)

	Maintenance and Management
Walkthrough (1)	No Observations
Review of documents (2)	Complaints about 'maintenance of water, heating and ventilation systems' and also 'late response of maintenance management'
Questionnaire Survey (3)	Dissatisfaction with 'maintenance of paving around the building' and 'communal greenery'
Physical Measurements (4)	No Observations
Focus group meetings (5)	Not discussed
Common issues identified from the evaluation methods above	Water heating and ventilation systems (2,3), Response of maintenance management (2,3)
	Layout, Furniture and Spatial Comfort
Walkthrough (1)	No Observations
Review of documents (2)	Complaints about the size of the maid's room and the size of toilet and bath (T/B) in the master's bedroom. Also concerns about the poor quality of carpentry work and air infiltration bringing dust into the building
Questionnaire Survey (3)	Dissatisfaction with 'space for landscaping', 'size of maid's bedroom' and 'quality of carpentry work for maid's bedroom'
Physical Measurements (4)	No Observations
Focus group meetings (5)	Concerns for increased size of maid's bedroom and washroom in the master's bedroom
Common issues identified from the evaluation methods above	Maid's bedroom (2,3,5), Space for landscaping (3)
	Housing Support Services
Walkthrough (1)	No Observations
Review of documents (2)	Complaints about over elevated bath-tubs in the masters bedroom, the need for a shower facility on the ground floor, high salinity of water for domestic use, improper location of toilet paper dispenser, small size of washroom facility in master's bedroom, and the need for children playground areas
Questionnaire Survey (3)	Dissatisfaction with 'the type of electrical outlets used', 'effectiveness of doors in preventing dust', 'storm water

	drainage system', 'accessibility to disabled and aged people', 'open spaces, parks and reserves', 'availability and children's play-ground and ladies centre', 'internet/television connection points'
Physical Measurements (4)	No Observations
Focus group meetings (5)	Availability of shower facility on ground floor; parks and open spaces, and the use of the drivers lodge should be reviewed
Common issues identified from the evaluation methods above	Over elevated bath tub (2), Shower facility on ground floor (2,5), High salinity of water (2), Parks and open spaces/children playground areas (2,3,5), Type of electrical outlets used (3), Effectiveness of doors in preventing dust (3), Storm water drainage (3), Accessibility of disabled (3), IT/TV connection points (3), Use of drives lodge (5)
	Privacy and Territoriality
Walkthrough (1)	No Observations
Review of documents (2)	Complaints about privacy due to close proximity of neighbouring buildings
Questionnaire Survey (3)	Satisfaction with all indicators
Physical Measurements (4)	No Observations
Focus group meetings (5)	Privacy concerns due to close proximity of other buildings
Common issues identified from the evaluation methods above	Privacy (2,5)
	Location
Walkthrough (1)	No Observations
Review of documents (2)	No Complaints
Questionnaire Survey (3)	Satisfaction with all indicators
Physical Measurements (4)	No Observations
Focus group meetings (5)	Not discussed
Common issues identified from the evaluation methods above	All evaluation methods corroborate each other
	Appearance

Walkthrough (1)	Corrosion of fixtures in washroom
Review of documents (2)	Complaints about paints, tiles, stains on the walls, and corrosion of fixtures in the washrooms, landscaping of the estate and general appearance
Questionnaire Survey (3)	Dissatisfaction with 'quality of materials used in floors', 'green areas (vegetation)', 'landscaping of neighbourhood', and 'general aesthetic appearance'
Physical Measurements (4)	No Observations
Focus group meetings (5)	Not discussed
Common issues identified from the evaluation methods above	Corrosion of fixtures (1,2), Quality of paints, tiles and stains on walls (2,3), Landscaping of estate & general appearance (2,3)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary, conclusions and recommendations of this study. Also presented herein are the contributions to theory and knowledge, contributions to practice, limitations of this research and suggestions for future study.

5.1 Summary: POE Holistic Framework

Few studies have been carried out in the POE of residential housing facilities, while the studies carried out so far fall short in the procedures and techniques used. This study however has sought to fill in the gap by developing a holistic POE tool which takes into consideration demographics, physical observations, interviews and a comprehensive questionnaire tool that considers various building performance features. This type of methodology will help to achieve a robust and more realistic decision making process for facility managers, housing administrators, designers, engineers and all stakeholders of the building and construction industry at large.

The holistic framework methodology proposed in this study is presented in figure 6. The figure shows the three main components of a holistic POE which are: demographics; multiple techniques; and value-based recommendations. Demographics will help to understand the nature of users of the buildings and examine the social and cultural factors that might contribute to their perception of the residential environment.

Multiple techniques allows for cross validation of data through the application and combination of several observations such as walkthroughs, instrumental observations, interviews, questionnaire surveys, review of existing documents and focus group meetings.

'Value-based recommendation' is a systematic process of making feedback based on the results of the POE study. It involves freewheeling of ideas as alternative solutions to the issues identified by the POE study, and afterwards validation of these alternatives by experienced professionals through interviews.

Chapter 3 of this research is a detailed discussion of the holistic POE methodology, performance elements and measurement methods. The performance elements identified by the study are: 'thermal comfort', 'indoor air quality', 'visual comfort', 'acoustic comfort', 'safety and security', 'health', 'management and maintenance' in the technical category; 'layout, furniture and spatial comfort', 'housing support services' in the functional category; and 'privacy and territoriality', 'location' and 'appearance' in the behavioural category.

5.2 Main Findings

This study has presented a holistic framework for the POE of residential housing facilities for a more comprehensive evaluation, holistic results and valuable recommendations. The POE of residential housing facilities is relatively new and still not well known. This study provides a methodology and tool for stakeholders in the building industry interested in POE studies. It fulfils the need for improving quality in the building construction industry, ensuring the comfort, health and well being of building occupants, and ultimately a sustainable outcome. Chapters 2 and 3 present a detailed literature review of POE and its related concepts, its evolution and measurement techniques, POE tools and frameworks, previous studies, performance elements and measurement methods, the design and methodology of this research and finally a review of the case study. Chapter 4 is a detailed discussion of the results of this study based on the application of the POE methodology and tool to the case study.

In particular, the findings of this study according to the research objectives listed in section 1.4 are as follows:

5.2.1 Objective 1: To develop a holistic framework for Post Occupancy Evaluation of residential housing facilities. The framework thus developed has been presented in figure 6 and discussed in sections 3.1 to 3.5. The POE questionnaire tool accompanying the framework is also presented in appendix K. The following is a list of the conclusions drawn:

1. Building performance elements were classified into three categories of building performance: Technical, Functional and Behavioural Categories. Technical performance elements deal with issues of Indoor Environmental Quality (IEQ) which affect the comfort, health and productivity of occupants, and issues of health, safety and security. Functional performance elements deal with the functionality and efficiency level of the features in the housing. These include: accessibility; spatial capacity for activities; and adequacy of necessary facilities such as: utilities; telecommunications; and efficiency of

communication and circulation. Behavioural performance elements pertain to the social, psychological, cultural and aesthetic level. Behavioural elements link occupants’ activities with the physical environment. These include issues of privacy; social interaction; image and appearance of the residential environment.

2. Twelve (12) performance elements were identified under the mentioned three categories. Seven (7) performance elements in the technical category, two (2) performance elements in the functional categories, and three (3) performance elements in the behavioural category. A thorough literature review of all performance elements has been provided to include different terminologies used, definitions, measurement methods and code requirements. A list of performance indicators used in previous studies was also listed.

3. The list of performance indicators was further identified under each performance element, a total of 237 performance indicators was identified and after revision and checking for redundancy, they were further reduced to 217. The number of performance indicators according to the performance elements are: 'Thermal Comfort': 10 indicators; 'Indoor Air Quality': 9 indicators; 'Acoustic Comfort': 8 indicators; 'Visual Comfort': 11 indicators; 'Safety and Security': 15 indicators; 'Maintenance and Management': 32 indicators; 'Health': 9 indicators; 'Layout, Furniture and Spatial Comfort': 37 indicators; 'Housing Support Services': 44 indicators; 'Privacy and Territoriality' 7 indicators; 'Location': 21 indicators; 'Appearance': 14 indicators.

This list of indicators was divided into five (5) sections and was presented to professional experts with relevant experience in the residential housing for validation, inclusion and checking for clarity. These sections are: "Indoor Environment" assessed by architectural engineers; "Safety and Security" assessed by architects and architectural engineers; "Building Maintenance" assessed by supervisors working in projects and maintenance departments; "Health" assessed by medical doctors; "Planning and Architecture" assessed by architects. Also a pilot survey was conducted with three (3) occupants of Al-Marooj courts. This exercise resulted in the removal of indicators in the 'Health' section due to feed-back from medical doctors that it is irrelevant to the residential housing context. Other performance indicators not applicable to single family residential housing facilities have also been excluded. A final list of 183 feasible performance indicators was included in the holistic questionnaire tool. Importance ratings for each performance indicator was also obtained from the professional experts.

5.2.2 Objective 2: To apply the POE framework to a case-study of the newly occupied Al-Marooj Courts at King Fahd University of Petroleum and Minerals. The results are presented in chapter 4. Presented here is a list of conclusions that can be drawn from the results:

1. Architectural drawings for both 4 and 5 bedroom apartments and the maintenance work order were reviewed to ensure that all likely performance indicators were included in the questionnaire tool. A list of problems (see appendix D) reported by occupants of Al-Marooj Courts to the campus maintenance department was used in this study as a substitute for the maintenance work order. A number of complaints were identified through the

maintenance work order such as: strong air flows; poor performance of thermostats; complaints about lighting levels in some spaces; noise from HVAC system amongst many others. See section 4 and Appendix D.

2. A walk-through around the facility identified issues such as strong air flows from the HVAC system, poor control of thermostat, accumulation dust around exit doors, low light levels in some living spaces, noise from vents in kitchens and washrooms, and corrosion of some of the washroom fixtures.

3. The questionnaire contained both closed and open ended sections. Open-ended sections were used to derive more qualitative feedback from respondents. The results are presented in appendix L. A likert scale of 1-5 was used for the questionnaire with a range from very dissatisfied to very satisfied. The questionnaire survey also includes a section where the demographic characteristics of the respondents are recorded. Questionnaire administration was carried out by means of postal mails and E-mails and follow-up was done through sending reminder E-mails and phone calls.

4. The total population of 90 was targeted in the study and the total number of usable feedback was 35 above one-third of the population and a representative sample of the population. All questionnaires were answered by the heads of the house-holds who are academic doctors, and thus are highly educated. Saudis represent the highest percentage (23.53%) of the population. Respondents from Canada and Jordan form the second largest group in this study with 9% each. Families dominated by adult members (above 18 years

of age) represent (67.65%) of the total population while families dominated by children represent (29.41%). A large percentage of respondents (85.29%) have stayed in the housing for over 12 months and most of the respondents (64.71%) stay at home for more than 12 hours daily.

5. The results of the questionnaire were analysed using a combination of descriptive and inferential statistics. Calculated values of Relative Importance Index (RII), the total number of respondents for each indicator (N), the Mean Satisfaction Index (MSI), and the standard deviation (SD) were presented in tables. All calculations were made with the aid of Minitab statistical software package. The neutral value of '3.00' was used as the mark for satisfaction according to Mohit & Azim, 2012. Some of the performance indicators that fall below the level of satisfaction include: 'indoor temperature shifts', 'control of thermostat', 'Noise from air/HVAC system', 'security system', 'quality and perception of fire safety systems in the building', 'quality of provided speed bumps', 'maintenance of paving around the building', 'communal greenery', 'space for landscaping', 'size of maid's bedroom', 'quality of carpentry work for maid's bedroom', 'the type of electrical outlets used', 'effectiveness of doors in preventing dust', 'storm water drainage system', 'accessibility to disabled and aged people', 'open spaces, parks and reserves', 'availability and children's play-ground and ladies centre', 'internet/television connection points', 'quality of materials used in floors', 'green areas (vegetation)', 'landscaping of neighbourhood', and 'general aesthetic appearance'.

6. The Importance-Satisfaction (I-S) analysis matrix which shows the strengths and failures of the residential environment was further used to analyse the results. Most of the performance indicators fall within the strengths region, however 'Noise from the HVAC system', 'control of thermostats', 'space for landscaping', and 'quality of materials used in floors' are some of the issues identified as priorities for improvement.

7. Spot measurements were carried out for lighting levels, sound levels, air temperature, relative movement, and air velocity. Results include:

i. 20.5^{o}C air temperature, 65% relative humidity and 3.5m/s air movement. Thus the measured temperature was below (22-27^{o}C) specified by ASHRAE standard 55, 2004. The relative humidity of 65% was above the recommended range stipulated by ASHRAE 62.1, 2004. If this value exceeds 70% for extended periods, it will promote the growth of some forms of mould and fungi.

ii. For noise measurements, a maximum value of 70.5dBA was recorded in the kitchen, see table 33 for results of the noise measurements. The minimum measured value of 50dBA in two of the bedrooms exceeds 35 – 45 dBA specified for private residential buildings.

iii. Lighting levels were identified as inadequate in the study and bedrooms. A measure in the range of 55Lux to 150Lux is below the allowable lighting levels as per the IESNA standards which is 200 – 500 Lux for kitchens and living rooms; and 500 – 1000 Lux for the study-room.

8. Inferential statistics was made including two-sample T-tests of two occupancy groups and a multi-linear regression analysis of respondents overall satisfaction indices. The mean value of the overall residential satisfaction is calculated to be 64.97 showing a moderate residential satisfaction according to Mohit et al., 2010 'regime of satisfaction'. Also the results of the two-sample T test show that occupancy profile is not a factor in determining respondents' satisfaction with the residential environment. The multi linear regression analysis also show that 'indoor temperature in summer', 'maintenance of paving around the building', 'noise from people between rooms', 'quality of materials used in floors', 'indoor temperature shifts' are from the most significant factors contributing to the overall residential satisfaction of occupants.

9. Finally, a focus group meeting was conducted to discuss the following issues: 'performance of HVAC system'; 'lightning system'; 'size of maids bedroom'; 'size of washroom in masters bedroom'; 'availability of shower facility on the ground floor'; 'availability of parks and open spaces'; 'privacy'; and 'driver's lodge'. Four participants of Saudi, Egyptian, Sudanese and Indian nationalities were selected for the exercise. Through the focus group meeting it was confirmed that the results gotten from previous POE evaluation was accurate.

5.3 Recommendations from Post Occupancy Evaluation

The issues identified through an integration of all evaluation techniques form the basis for recommendations to serve as feed-back to the existing housing stock and feed-forward for future housing developments. These are presented in seven (7) categories including: architectural design/construction; safety and security; furniture, fixtures and equipments; heating and ventilation system; quality assurance; maintenance and management; and general recommendations.

5.3.1 Architectural Design/Construction

1. A shower facility on the ground floor should be provided to be of potential service to the disabled, old-aged and guests. It is recommended that the washroom facility opposite the reception on the ground floor can be modified to incorporate a shower facility. See ground floor plan, appendix C.
2. Noise between spaces can be controlled with the use of block walls of 45-50dB sound resistance. The type of carpets and furniture in the living space can also be selected to serve as sound proof.
3. 40% of the total size of the estate should be set aside to provide facilities such as children playground areas, communal greenery, landscaping and paving, parks and reserves.
4. Bus stops should be shaded for due consideration of the heat in summer and rain
5. The maid's bedroom as well all living rooms should have a minimum size of 3m X 3m. Space for the maid's room can be created by adjusting the size of the stair and adjacent room. See first floor plan, appendix C.

6. Increase the size of washroom facility in the master bedroom. A minimum size of 3m X 4m should be provided. With sufficient spacing between toilet facilities.
7. Toilet paper dispenser should be at the right hand side of the user and reachable within an arm's length.
8. Accessibility to disabled and aged people should be provided by incorporating ramps at exits and grabs in washroom facilities. It is recommended that at least one of the wash room facilities at the ground floor should be designed for people with limited mobility according to universal design standards.
9. Correct grading and slope for surrounding compounds to prevent ponding and to allow effective storm-water drainage.
10. Provide facility for ladies for social activities within the estate
11. Improve the quality of carpentry work
12. Privacy walls can be incorporated along the buildings' perimeter for better privacy

5.3.2 Safety and Security

1. Provide security system such as surveillance camera, and burglar alarms
2. Electricity panel boards should be accessible for cases of emergency and kept away from children's reach
3. Provide speed controls like bumps and speed limit signs to reduce over speeding within the estate
4. Prevent the entry of insects and ants by proper sealing of door edges
5. Appropriate safety measures should be provided for gas outlets in kitchen

6. Provide sprinklers, smoke, fire alarms and heat detection systems according to IBC, 2012 and NFPA code requirements
7. Adequate safety/construction signs and barriers should be provided in new construction areas
8. Replace windows which can be opened from the exterior of the building to prevent burglar
9. Provide adequate exterior lighting to prevent vandalisation and ensure safety and security

5.3.3 Furniture, Fixtures and Equipments (FF & E)

1. Ensure lighting levels meet up to the required standards provide by IESNA (table 10). 200 – 500 Lux for living areas with visual tasks of high contrast or large size like the kitchens and living rooms. And 500 – 1000 Lux for visual tasks of medium contrast or small size like the study.
2. Maid's room as well as all other rooms should have minimum required furniture including: a bed, dresser and ward-robe.
3. Provide 3-pin large 220V adaptors for all outlets
4. Provide high quality exterior wood or metal doors to ease its closing in summer when doors expand. Also ensure exterior doors are well sealed and tightened to prevent dust/sand infiltration and energy loss
5. Each washroom facility should have a water control valve aside the centralized valve existing for flexibility
6. Provide sweet water in all faucets, otherwise salinity of water should be controlled for domestic use. The World Health Organisation recommends 1500

mg/ L as the maximum level for human consumption, though over 1000 mg/L may be associated with excessive scaling, corrosion and unsatisfactory taste.

7. A water faucet should be provided in the backyard for outdoor activities.
8. Gates should be opened from inside the villa for visitors by door opening mechanisms.
9. Provide IT outlets in rooms for inter-phone
10. Increase size of refrigerators provided. A large size ($24ft^3$) is preferable

5.3.4 HVAC

a. Create more zones for thermostat control. Alternatively multi thermostats can be used. Or the thermostats can be located in a strategic position where the temperature represents the average temperature in the representative zone. It should be removed from the hallway.
b. The HVAC filter should be checked for clogging as well as the internal pressure within the building to ascertain the cause of dusts
c. HVAC contractor should do a testing and balancing exercise to control air flow and review maintenance program. In this exercise, the capacity (temperature and air flow), air balance and air distribution should be measured, and subsequently recommendations should be provided to facilitate even distribution of temperature and minimise indoor temperature shifts.
d. The HVAC system should be evaluated for potential noise sources like vibration

5.3.5 Quality Assurance

1. Improve on the quality of construction materials and supervision of construction work for kitchen and bathroom tiles.
2. Specify paints that can resist wear due to humidity like enamel paints. And specifications should be adhered to.
3. Ensure quality damp-proof is specified, and they are well joint in construction and not damaged to prevent water leakage in roof and first floor.
4. Ensure compaction of surrounding grounds before laying of concrete slabs to stop the breakage of the slabs due to differential settlement.
5. Quality supervision in construction of bath-tubs to be within the maximum height of 645mm, should be ensured for ease of use
6. Provide high quality of hinges, locks and toilet fixtures which are corrosion-resistant
7. Ensure quality review of design/construction to match standards

5.3.6 Maintenance and Management

1. Extractor fans should be well maintained to reduce dust and noise
2. Provide pipe chase for water lines to avoid demolition during maintenance and leakage repair
3. Review network design to speed-up hot water delivery at faucets in winter. Alternatively a "point of use" hot water system can be installed.
4. Review maintenance plan for water heaters due to its frequent dysfunction

5. Review HVAC maintenance program. Preventive Maintenance (PM) once or twice a month is preferred. A PM checklist should be developed and results from the exercise be provided to the administration at regular intervals
6. Improve on speed, efficiency and frequency of maintenance
7. Responsibility for repair and replace should be taken by maintenance department

5.3.7 General

1. Provide fast, reliable and efficient maintenance response
2. Improve on design and construction quality
3. Improve general aesthetic appearance and construction finishing
4. Employ universal design (UD) standards to ensure adequate support for people with limited mobility

5.4 Contributions to Theory and Knowledge

The following contributions can be attributed to this study:

1. This study presents an extensive review of literature on Post Occupancy Evaluation, it chronicles its origin and evolution and its related sub-topics, it also highlights various methods used and performance elements to be considered in carrying out a post occupancy evaluation, also a review of industry tools/framework and techniques available is presented and finally benefits and barriers to the implementation of POE. It is hoped that the review presented in this study will serve as a foundation and background reference for subsequent research.

2. This study also presents a more robust approach to evaluation of residential housing facilities. This is through the presentation and application of a holistic POE methodology and questionnaire tool that comprehensively covers as many performance elements as possible. Previous researchers have suggested that holistic approaches to POE should be given priority in the property sector.

5.5 Contributions to Practice

The benefits of a POE study has been discussed in section 2.4 which is broadly classified into two: 'continuous improvement' and 'feed-forward to the construction industry'. This study has also presented its recommendations in section 4.4. However a number of practical conclusions and recommendations drawn from this study is listed as follows:

1. Project and Facility managers in particular and stake-holders of the built environment in general should pay more attention to POE studies for residential housing developments. This will ensure that quality is assured in construction and there is a continuous learning process from past projects and operated facilities for a healthy and more sustainable built environment.

2. The holistic approach presented in this study should be the preferred method for POE studies so as to arrive at real evaluation results and subsequently proffer realistic and valuable recommendations.

3. Post Occupancy Evaluations should be carried out periodically for residential compounds in the same geographic location and results and recommendations should be systematically documented to create a data base. This database will facilitate benchmarking and consequently help to improve quality and serve as a wealth of resource for the construction professional practise.

4. Professionals should attend workshops and training sections on Post Occupancy Evaluations as suggested in section 2.5.4. Since insufficient knowledge and training is one of the hindrances to POE studies. Results from POE studies should also be shared amongst the stakeholders of a residential housing development so that knowledge is effectively transferred.

5. Professional bodies in construction and sustainable housing development should seek to develop POE tool kits for their professional members for ease of its application, uniformity in procedure and effective feed-back and feed-forward.

5.6 Limitations of the Research

Although this study has presented a holistic POE tool, this study faced some limitation in data collection and data analysing process. The professional survey was conducted by professionals in the eastern province of Saudi Arabia. A minimum of three professionals for five categories presented in appendixes F to J was selected to validate the questionnaire. To achieve better accuracy a larger sample size and thorough revision of the questionnaire tool might be required.

The sample size of the occupants was 35, which was proved to be adequate for a population size of 90. Any potential flaw of this sample size has been overcome by the results obtained from other evaluation methods, such as the open-ended sections of the questionnaires, physical measurements, walk through and focus group meetings.

Physical measurements taken in this study was delimited to spot measurements of carbon oxide (CO), carbon dioxide (CO_2), particles, lighting, sound levels, air velocity, relative humidity and air temperature. The building provided for the evaluation was a building which was vacated six months before the evaluation with all furniture removed, thus the setting was not a typical occupied residential setting. This however is a limitation only for the air quality, and has no significant effect on other parameters measured like the lighting and sound levels.

5.7 Suggestions for Future Research

The following are future research suggested based on knowledge from this study:

In this study, a holistic framework has been developed for POE and consequently applied on a case-study. It is however suggested that another research be carried out to further validate the framework with a larger number of professionals and then compare its findings with the findings of this study. Yet another research will be to apply the framework in this paper on a separate case study and thus compare its findings with the findings of this study.

A research that will develop a similar framework for multi-family residential buildings is also suggested. It will contain some unique performance indicators like lifts, shared areas, balconies etc.

The last suggestion for future research should be a long term work where the POE holistic tool can be further developed and standardised, and subsequently applied to a large number of case studies to create a publicly-accessible data base for benchmarking and effective feed-forward of knowledge to the construction industry.

References

1. Abbaszadeh, S., Zagreus, L., Lehrer, D., & Huizenga, C. (2006). Occupant satisfaction with indoor environmental quality in green buildings.
2. AlSaati, M.Z. (2006). An Open building application to duplex house in Saudi Arabia. *Masters thesis published by King Faisal University*.
3. Al Shimemeri, S. A., & Patel, C. B. (2011). Assessment of noise levels in 200 Mosques in Riyadh, Saudi Arabia. *Avicenna journal of medicine, 1(2), 35.*
4. Amole, D. (2009). Residential satisfaction in students' housing. *Journal of Environmental Psychology*, *29*(1), 76-85.
5. Anderson, A., Cheung, A., & Lei, M. (2014). Evaluation of Hong Kong's indoor air quality management programme: certification scheme, objectives, and technology.
6. ASHRAE, A. S. (2004). ASHRAE 55-2004, *Thermal environmental conditions for human occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.
7. ASHRAE, A. (2004). ASHRAE 62.1-2004, *Ventilation for Acceptable Indoor Air Quality*. American society of heating, refrigerating and air-conditioning engineers.
8. AUDE (2006), *Guide to Post Occupancy Evaluation*, AUDE and the University of Westminster, London, UK
9. Baird G., Gray, J., Isaacs, N., Kernohan, D., & McIndoe, G. (1996). Building evaluation techniques. New York: McGraw-Hill.
10. Ben Lasod, S.A. (2013). Development of an assessment tool for maintenance management in public schools in Saudi Arabia. *Masters thesis published by King Fahd University* of Petroleum and Minerals.

11. Bordass, B., & Leaman, A. (2005). Making feedback and post-occupancy evaluation routine 1: A portfolio of feedback techniques. *Building Research & Information*, *33*(4), 347-352.

12. Bordass, B., & Leaman, A. (2005). Making feedback and post-occupancy evaluation routine 3: Case studies of the use of techniques in the feedback portfolio. *Building Research & Information*, *33*(4), 361-375.

13. Brown, S. K. (1997). Indoor air quality. Environment Australia.

14. Budaiwi, I., & Abdou, A. (2013). The impact of thermal conductivity change of moist fibrous insulation on energy performance of buildings under hot–humid conditions. *Energy and Buildings*, *60*, 388-399.

15. Burnett, J. (2005). Indoor air quality certification scheme for Hong Kong buildings. *Indoor and Built Environment*, *14(3-4), 201-208.*

16. CertainTeed Corporation. Noise Control for Buildings: Guidelines for Acoustical Problem solving (Pp. 6-8) http://www.certainteed.com/resources/NoiseControl%20Brochure%2030-29-121.pdf

17. Choi, J. H., Loftness, V., & Aziz, A. (2012). Post-occupancy evaluation of 20 office buildings as basis for future IEQ standards and guidelines. *Energy and buildings*, *46*, 167-175.

18. Clift, M. (1996). Building quality assessment (BQA) for offices. *Structural Survey*, *14(2), 22-25.*

19. Council, F. F. (2001). *Learning from our buildings: A state-of-the-practice summary of post-occupancy evaluation* (Vol. 145). National Academies Press.

20. da CL Alves, T., Costa, G. S., & de P Barros Neto, J. (2009). Creating value in housing projects: the use of post-occupancy analysis to develop new projects. In *Construction Research Congress 2009@ sBuilding a Sustainable Future* (pp. 1105-1114). ASCE.

21. Dall, G. (2013). *Green Energy Audit of Buildings, a guide for a sustainable energy audit of buildings*. Springer London.

22. David Jiboye, A. (2012). Post-occupancy evaluation of residential satisfaction in Lagos, Nigeria: Feedback for residential improvement. *Frontiers of Architectural Research*, *1*(3), 236-243.

23. Department of Defence, United States of America, 2003. Unified Facilities Criteria (UFC): Noise and Vibration Control http://www.wbdg.org/ccb/DOD/UFC/ufc_3_450_01.pdf

24. Deuble, M. P., & de Dear, R. J. (2014). Is it hot in here or is it just me? Validating the post-occupancy evaluation. *Intelligent Buildings International,* (ahead-of-print), 1-23.

25. Fatoye, E. O., & Odusami, K. T. (2009). Occupants' satisfaction approach to housing performance evaluation: the case of Nigeria. In *RICS COBRA research conference held at the University of Cape Town* (Vol. 10).

26. Fellows, R. F., & Liu, A. M. (2009). *Research methods for construction*. John Wiley & Sons.

27. Finch, E. (1999). Empathetic design and post-occupancy evaluation. *Facilities*,*17*(11), 431-435.

28. Fisk, D. (2001). Sustainable development and post-occupancy evaluation. *Building Research & Information, 29(6), 466-468.*

29. Frontczak, M., Schiavon, S., Goins, J., Arens, E., Zhang, H., & Wargocki, P. (2012). Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design. *Indoor Air, 22(2), 119-131*.

30. Gou, Z., Lau, S. S. Y., & Zhang, Z. (2012). A comparison of indoor environmental satisfaction between two green buildings and a conventional building in China. *College Publishing*, *7*(2), 89-104.

31. Gray, J., Isaacs, N., Kernohan, D., & McIndoe, G. (1996). *Building evaluation techniques*. New York: McGraw-Hill.

32. GSA, (2011). Sound Matters: How to achieve acoustic comfort in the contemporary office. Produced by GSA Public Buildings Service, December 2011

33. Hartkopf, V. H., Loftness, V. E., & Mill, P. A. (1986). The concept of total building performance and building diagnostics. *Building Performance*, 5-22.

34. Hassanain, M. A. (2008). On the performance evaluation of sustainable student housing facilities. *Journal of Facilities Management, 6(3), 212-225.*

35. Hassanain, M.A., Sedky, A., Adamu, Z. A., & Saif, A. W. (2010). A framework for quality evaluation of university housing facilities. *Journal of Building Appraisal*, *5*(3), 213-221.

36. Ho, D.C.W., Chau, K.W., King-Chung Cheung, A., Yau, Y., Wong, S.K., Leung, H.F., & Wong, W.S. (2008). A survey of the health and safety conditions of apartment buildings in Hong Kong. *Building and Environment, 43(5), 764-775*.

37. Hwang, T., & Kim, J. T. (2011). Effects of indoor lighting on occupants' visual comfort and eye health in a green building. *Indoor and Built Environment*, *20(1), 75-90*.

38. Ibem, E. O. (2011). *Evaluation of public housing in Ogun State*, Nigeria (Doctoral dissertation, Covenant University).

39. Ibem, E. O. (2013, September). Accessibility of services and facilities for residents in public housing in urban areas of Ogun State, Nigeria. In *Urban Forum* (Vol. 24, No. 3, pp. 407-423). Springer Netherlands.

40. Ilesanmi, A. O. (2010). Post-occupancy evaluation and residents' satisfaction with public housing in Lagos, Nigeria. *Journal of Building Appraisal*, *6*(2), 153-169.

41. Illuminating Engineering Society of North America (IESNA). (2000). *The IESNA Lighting Handbook: Reference and Application.* 9th edition. Ed M.S. Rea. New York: IESNA.

42. Inah Sylvester, A., Yaro Margaret, A., & Agbor Emmanuel, A. (2014). Residential Housing Satisfaction of the Urban Poor in Calabar Metropolis, Nigeria.

43. Jamaludin, A. A., Keumala, N., Ariffin, A. R. M., & Hussein, H. (2013). Satisfaction and perception of residents towards bioclimatic design strategies: Residential college buildings. *Indoor and Built Environment*, 1420326X13481614.

44. Khalil, N., & Nawawi, A. H. (2008). Performance analysis of government and public buildings via post occupancy evaluation. *Asian Social Science, 4(9), P103*.

45. Khalil, N., Husin, H. N., Adnan, H., & Nawawi, A. H. (2009). Correlation Analysis of Building Performance and Occupant's Satisfaction via Post Occupancy Evaluation for Malaysia's Public Buildings.

46. Khalil, N., & Husin, H. N. (2009). Post Occupancy Evaluation towards Indoor Environment Improvement in Malaysia's Office Buildings. *Journal of Sustainable Development*, *2*(1).

47. Khamidi, M. F., Wahab, S. N. A., & Zahari, N. M. (2013). Post occupancy evaluation (POE) and indoor environmental quality (IEQ) assessment: a case study of Universiti Teknologi Petronas new academic complex. *Journal of Design + Built*, *6*.

48. Kim, S. S., Yang, I. H., Yeo, M. S., & Kim, K. W. (2005). Development of a housing performance evaluation model for multi-family residential buildings in Korea. *Building and environment*, *40*(8), 1103-1116.

49. Lai, A. C. K., Mui, K. W., Wong, L. T., & Law, L. Y. (2009). An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings. *Energy and Buildings, 41(9), 930-936.*

50. Lai, A. W., & Pang, P. S. (2010). Measuring performance for building maintenance providers. *Journal of construction engineering and management*,*136*(8), 864-876.

51. Leaman, A. (2003). Post-occupancy evaluation. *Benchmarking Sustainable Building Performance.*

52. Leaman, A., & Bordass, B. (2007). Are users more tolerant of ‘green’buildings?. *Building Research & Information, 35(6), 662-673.*

53. Leaman, A., Stevenson, F., & Bordass, B. (2010). Building evaluation: practice and principles. *Building Research & Information*, *38*(5), 564-577.

54. Lee, Y. S., & Guerin, D. A. (2009). Indoor environmental quality related to occupant satisfaction and performance in LEED-certified buildings. *Indoor and Built Environment, 18(4), 293-300.*

55. Leifer, D. (1998). Evaluating user satisfaction: case studies in Australasia. *Facilities, 16(5/6), 138-142.*

56. Lesbirel, M. 2012 LEED® Post-Occupancy Surveys: Designing a survey for maximum return.

57. Li, B., & Lim, D. (2013). Occupant Behavior and Building Performance. In *Design and Management of Sustainable Built Environments* (pp. 279-304). Springer London.

58. Liu, A. M. M. (1999). Residential satisfaction in housing estates: a Hong Kong perspective. *Automation in Construction*, *8(4)*, *511-524*.

59. Martilla, J. A., & James, J. C. (1977). Importance-performance analysis. *The journal of marketing*, 77-79.

60. Matzler, K., Bailom, F., Hinterhuber, H. H., Renzl, B., & Pichler, J. (2004). The asymmetric relationship between attribute-level performance and overall customer satisfaction: a reconsideration of the importance–performance analysis. *Industrial Marketing Management*, *33*(4), 271-277.

61. Meir, I. A., Garb, Y., Jiao, D., & Cicelsky, A. (2009). Post-occupancy evaluation: an inevitable step toward sustainability. *Advances in Building Energy Research, 3(1), 189-219.*

62. Meir, I. A., Motzafi-Haller, W., Morhayim, L., Fundaminsky, S., & Oshry-Frenkel, L. (2012). Towards a comprehensive methodology for Post Occupancy Evaluation (POE): A hot dry climate case study. *development*, 5.

63. Menzies, G. F., & Wherrett, J. R. (2005). Windows in the workplace: examining issues of environmental sustainability and occupant comfort in the selection of multi-glazed windows. *Energy and Buildings, 37(6), 623-630.*

64. Moezzi, Mithra & John Goins. ―Using Text analysis to listen to building users. *Indoor Environmental Quality. (2010).*

65. Mohsini, R. A. (1989). Performance and building: problems of evaluation. *Journal of Performance of Constructed Facilities*, *3*(4), 235-242.

66. Mohit, M. A., Ibrahim, M., & Rashid, Y. R. (2010). Assessment of residential satisfaction in newly designed public low-cost housing in Kuala Lumpur, Malaysia. *Habitat International, 34(1), 18-27*.

67. Mohit, M. A., & Azim, M. (2012). Assessment of residential satisfaction with public housing in Hulhumale', Maldives. *Procedia-Social and Behavioral Sciences*, *50*, 756-770.

68. Nawawi, A. H., & Khalil, N. (2008). Post-occupancy evaluation correlated with building occupants' satisfaction: An approach to performance evaluation of government and public buildings. *Journal of Building Appraisal*, *4*(2), 59-69.

69. Neuman, D. J. (2013). *Building type basics for college and university facilities* (Vol. 22). John Wiley & Sons.

70. Ng, B. H., & Akasah, Z. A. (2013). Post Occupancy Evaluation of energy-efficient buildings in tropical climates-Malaysia. *ArchNet-IJAR*, *7*(2).

71. Nooraei, M., Littlewood, J. R., & Evans, N. I. (2013). Feedback from Occupants in 'as Designed' Low-carbon Apartments, a Case Study in Swansea, UK. *Energy Procedia*, *42*, 446-455.

72. Nor' Aini Yusof, Abidin, N.Z., & Najib, N.U.M. (2013). Performance of Housing Maintenance in Public Housing. *Journal of Economics and Sustainable Development*, *4(6), 156-163.*

73. Pfafferott, J. Ü., Herkel, S., Kalz, D. E., & Zeuschner, A. (2007). Comparison of low-energy office buildings in summer using different thermal comfort criteria. *Energy and Buildings, 39(7), 750-757*.

74. Preiser, W. F., Rabinowitz, H. Z., & White, E. T. (1988). *Post-occupancy evaluation*. New York: Van Nostrand Reinhold.

75. Preiser, W. F. (1995). Post-occupancy evaluation: how to make buildings work better. *Facilities*, *13*(11), 19-28.

76. Preiser, W. F. (Ed.). (1989). *Building evaluation*. Springer.

77. Preiser, W. F. (2001). Feedback, feedforward and control: post-occupancy evaluation to the rescue. *Building Research & Information, 29(6), 456-459.*

78. Preiser, W. F., & Ostroff, E. (Eds.). (2001). *Universal design handbook*. McGraw Hill Professional.

79. Preiser, W. F., & Vischer, J. (Eds.). (2005). *Assessing building performance*. Routledge.

80. Preiser, W. F., & Nasar, J. L. (2008). Assessing building performance: Its evolution from post-occupancy evaluation. *International Journal of Architectural Research*, *2*(1), 84-99.

81. Preiser, W.F., Davis, A.T, & Salama, A.M. (Eds.) (2015). *Architecture beyond Criticism: Expert Judgment and Performance Evaluation*. Abingdon, UK: Rutledge.

82. Pritam, B., & Mukta, B. (2012). A Post-occupancy Evaluation of Patient's Perception of Visual Comfort in Hospital Wards. *International Journal of Environmental Sciences*, *3*(3).

83. Richman, E. E. Requirements for Lighting Levels. http://www.wbdg.org/pdfs/usace_lightinglevels.pdf

84. Riley, M., Kokkarinen, N., & Pitt, M. (2010). Assessing post occupancy evaluation in higher education facilities. *Journal of Facilities Management*, *8*(3), 202-213.

85. Seshadhri, G., & Topkar, V. (2014). Validation of a Questionnaire for Objective Evaluation of Performance of Built Facilities. *Journal of Performance of Constructed Facilities*.

86. Shika, S. A., Sapri, M., Abdullah, D. J. S., Wakawa, U. B., Umar, A., & Umar, U. A. (2014, March). Post occupancy evaluation sustainability assessment framework for commercial office buildings. In *Recent Trends in Social and Behaviour Sciences: Proceedings of the International Congress on Interdisciplinary Behaviour and Social Sciences 2013* (p. 235). CRC Press.

87. Taylor, T., Littlewood, J., Geens, A., Counsell, J., & Pettifor, G. (2010). Developing post-occupancy evaluation techniques for assessing the environmental performance of apartment buildings in Wales: An ecological perspective.

88. Temple, P. (Ed.). (2014). T*he Physical University: Contours of Space and Place in Higher Education*. Routledge.

89. Turpin-Brooks, S., & Viccars, G. (2006). The development of robust methods of post occupancy evaluation. *Facilities*, *24*(5/6), 177-196.

90. Ukoha, O. M., & Beamish, J. O. (1997). Assessment of residents' satisfaction with public housing in Abuja, Nigeria. *Habitat International, 21(4), 445-460*.

91. Van Mossel, H. J., & Jansen, S. J. (2010). Maintenance services in social housing: what do residents find important?. *Structural Survey, 28(3), 215-229.*

92. Varady, D. P., & Preiser, W. F. (1998). Scattered-site public housing and housing satisfaction: Implications for the new public housing program. *Journal of the American Planning Association, 64(2), 189-207.*

93. Watson, C. (2003). Review of building quality using post occupancy evaluation (No. 2003/3). OECD Publishing.

94. Way, M., & Bordass, B. (2005). Making feedback and post-occupancy evaluation routine 2: Soft landings–involving design and building teams in improving performance. *Building Research & Information*, *33*(4), 353-360.

95. Williams, W. (1999). *Footcandles and lux for architectural lighting*. An introduction to illuminance. http://www.mts.net/~william5/library/illum.htm

96. Wong, N. H., & Jan, W. L. S. (2003). Total building performance evaluation of academic institution in Singapore. *Building and Environment*, *38*(1), 161-176.

97. Woon, N. B., Ramli, N. A., Zainol, N. N., & Mohammad, I. S. (2013). Barriers to the implementation of Post Occupancy Evaluation: a preliminary survey.

98. Zimmerman, A., & Martin, M. (2001). Post-occupancy evaluation: benefits and barriers. *Building Research & Information*, *29*(2), 168-174.

99. http://en.wikipedia.org/wiki/Eastern_Province,_Saudi_Arabia

100. http://foldoc.org/evaluation

101. http://www.etu.org.za/toolbox/docs/government/safety.html

102. http://www.tbs-sct.gc.ca/si-as/tools-outils/tools-outils04-eng.asp

APPENDIX A

(Milestones and contributions to POE of housing facilities (Adapted and modified from Preiser et al. 2015)

Year	Author(s)	Building Type	Contribution to the Field
1967	Van der Ryn & Silverstein	Student dormitories	Environmental analysis; concept and methods
1968	Sanoff	Any facility type	"Evaluation Techniques for Designers" – first monograph on POE
1969	Preiser	Student dormitories	Environmental performance profiles; correlation of subjective and objective performance measures
1972	Markus, et al.	Any facility type	Cost-based building performance evaluation model
1974	Becker	Public housing	Cross-sectional comparative approach to data collection and analysis
1976	Connell & Ostrander	Government facilities	"POEs of Postal and Enlisted Housing"
1978	Bechtel and Srivastava	Housing	Comprehensive review of POEs of Housing
1981	Palmer	Any facility type	Programming linked to POE methodology
1982	Parshall/Pena	Any facility type	Simplified and standardized evaluation methodology for practitioners
1987	Building Research Board	Any facility type	"POE Practices in the Building Process"
1988	Preiser, Rabinowitz & White	Any facility type	"Post-Occupancy Evaluation" – first book on POE Methodology

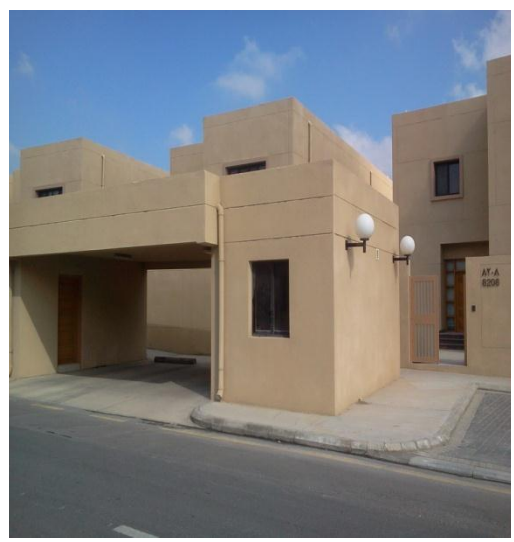
1989	Preiser	Any facility type	"Building Evaluation" – POE case studies from around the world
1992	Sanoff	Any facility type	Integrating programming, POE and user participation in design
1996	Baird, et al.	Any facility type	"Building Evaluation Techniques" – first comprehensive methods book
1997	Preiser & Schramm	Any facility type	"Building Performance Evaluation" – conceptual BPE framework
2001	Federal Facilities Council	Any facility type	"Learning From Our Buildings" – Federal POE/BPE overview
2003	NCARB	Any facility type	"Improving Building Performance" – a study guide for architects
2005	Bordass & Leaman	Any Facility Type	"Making feedback and post-occupancy evaluation routine" – techniques for effective feedback and stakeholder involvement
2005	Szigeti & Davis	Any facility type	Performance based building
2005	Preiser & Vischer	Any facility type	"Assessing Building Performance" – global BPE book
2006	Zeisel	Any facility type	Example POE- The Jerusalem Center for Multi-Handicapped Visually Impaired Children
2007	Nasar, Preiser & Fisher	Any facility type	"Designing for Designers: Lessons Learned from Schools of Architecture"
2007	Hartman	Any facility type	"Measuring a Buildings Success"- an article reviewing the potentials and fears of POEs for building

			designers
2008	Hassanain	Student dormitories	
2008	Gonchar	Any facility type	
2009	Ireland	Any facility type	Importance of collaboration and building analysis- examples using information about LEED and intelligent building design
2010	Spataru	E.ON Research House	Research on 'Creative Energy Homes'
2011	Borg	Any facility type	"A Dossier on Post-Occupancy Evaluation"
2012	Mallory-Hill, Preiser & Watson	Any facility type	"Enhancing Building Performance": State-of-the-art book on process model, methodology and case studies

Milestones and contributions to POE of housing facilities (Adapted and modified from Preiser et al. 2015)

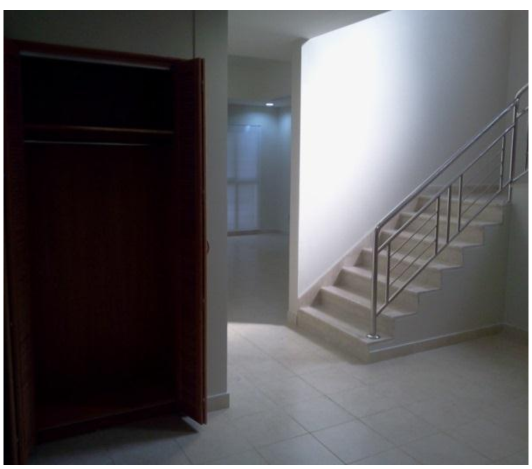
APPENDIX B

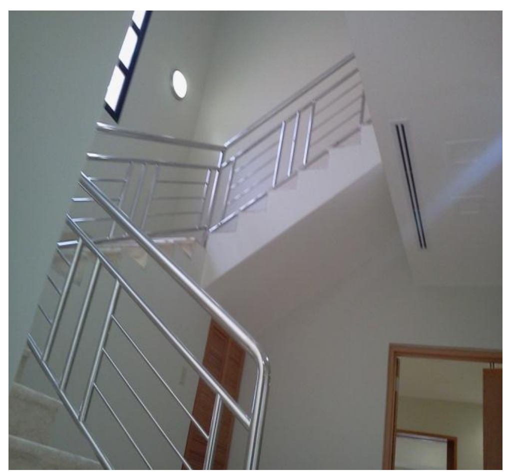
(Walkthrough Photos)

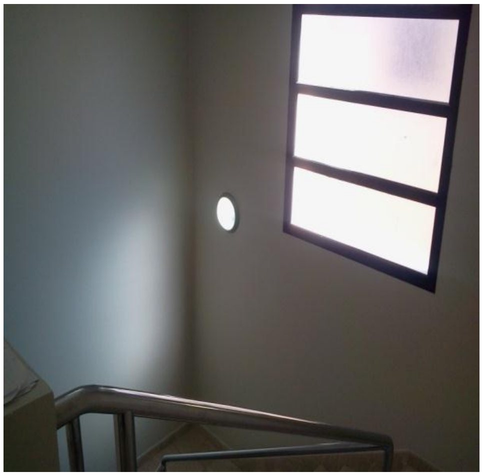


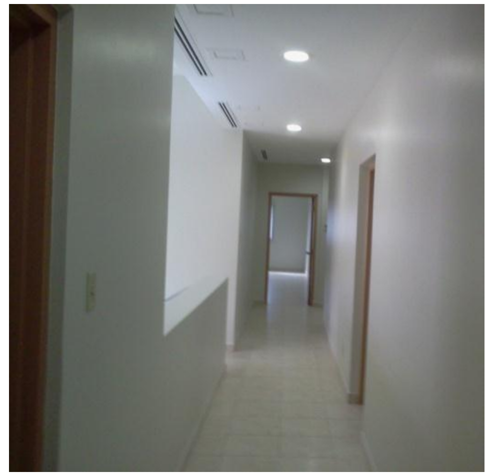






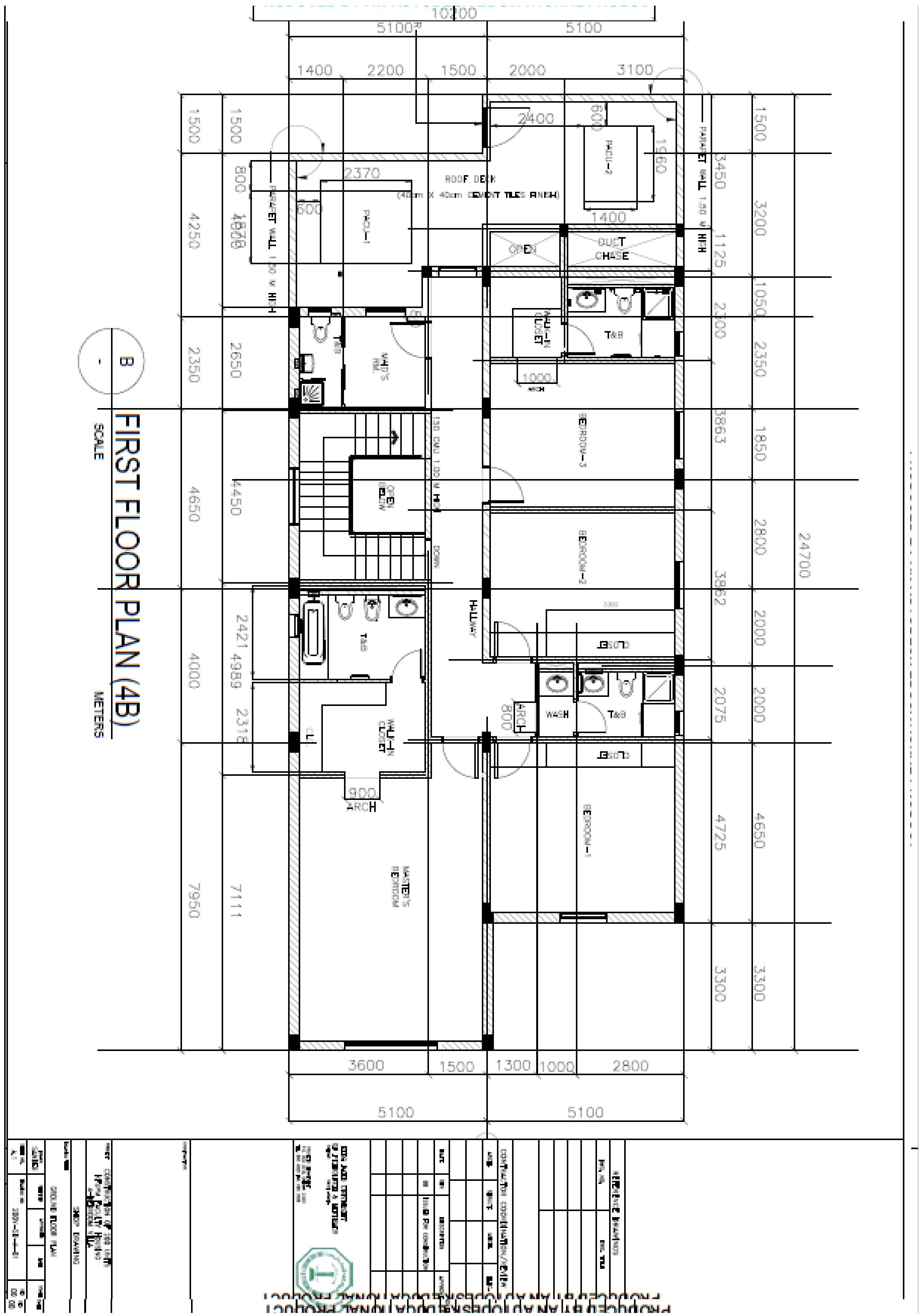


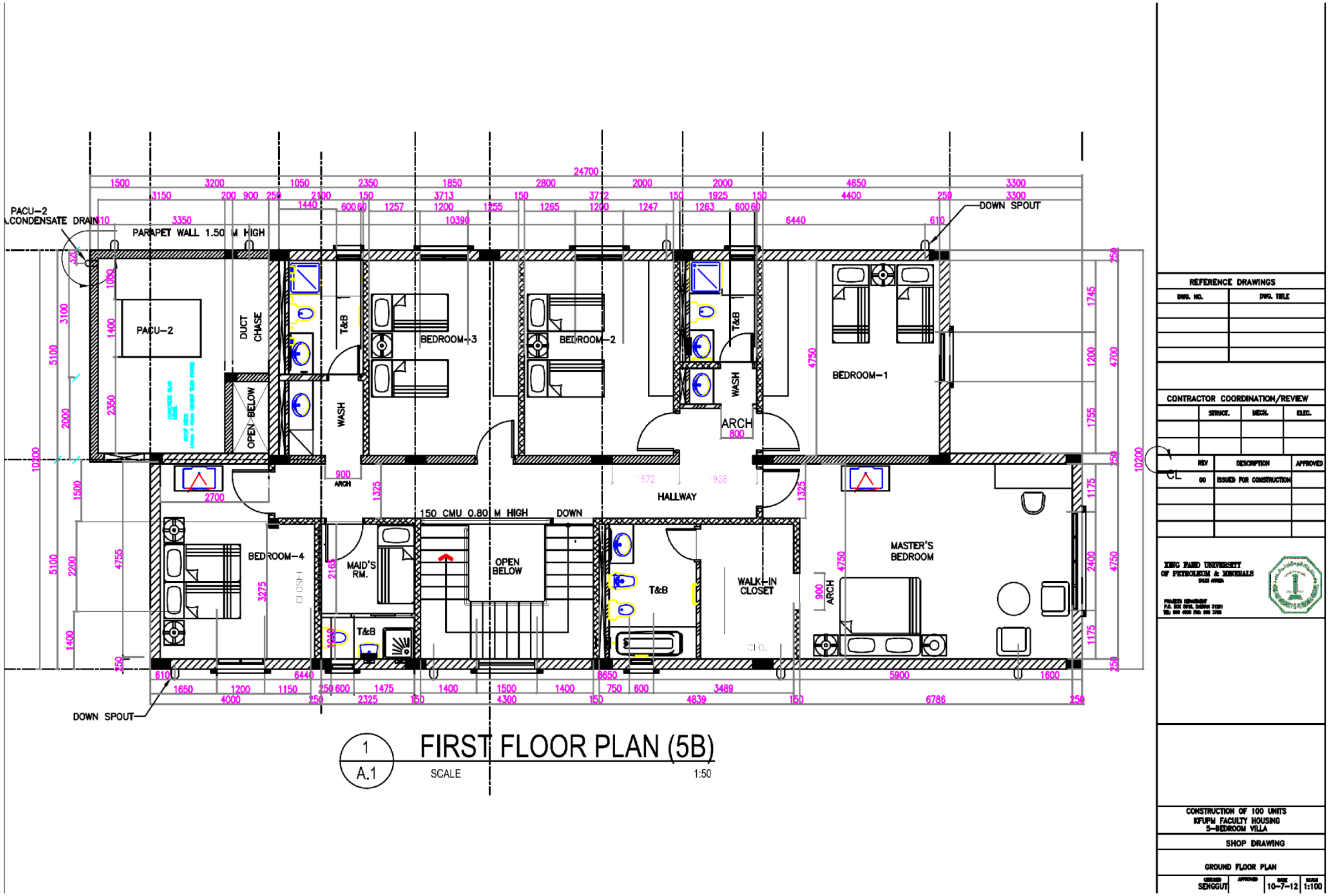


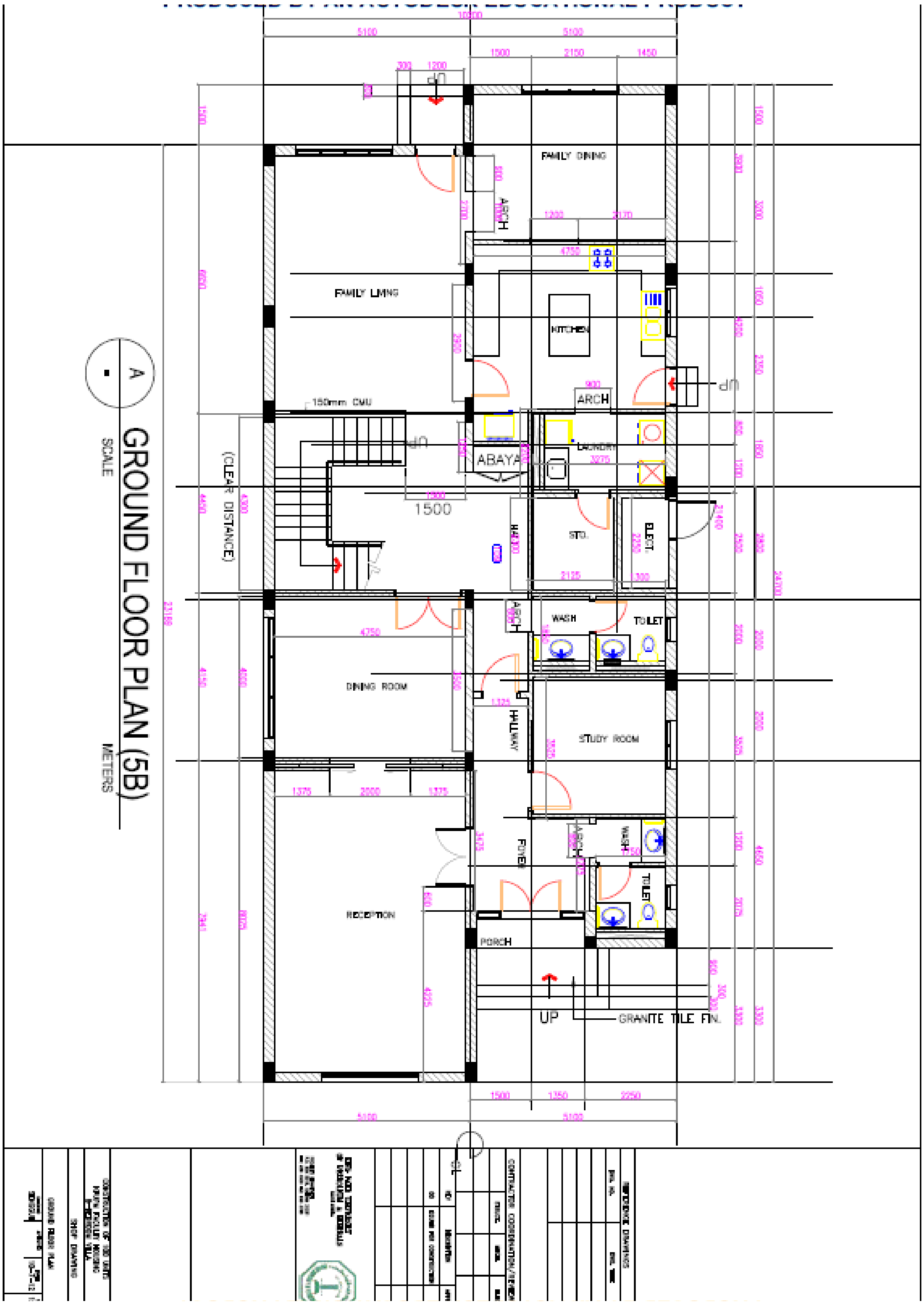


APPENDIX C

(Floor Plans)


FIRST FLOOR PLAN (4B)
SCALE
METERS
ROOF DECK
PARAPET WALL 1.50 M HIGH
OPEN
DUCT CHASE
T&B
WALK-IN CLOSET
BEDROOM-3
BEDROOM-2
BEDROOM-1
HALLWAY
CLOSET
WASH
ARCH
MASTER'S BEDROOM
OPEN BELOW
DOWN
10200
5100
24700


FIRST FLOOR PLAN (5B)
1
A.1
SCALE
1:50
PACU-2
A.CONDENSATE DRAIN
PARAPET WALL 1.50 M HIGH
DOWN SPOUT
PACU-2
DUCT CHASE
OPEN BELOW
T&B
WASH
ARCH
BEDROOM-3
BEDROOM-2
BEDROOM-1
BEDROOM-4
CLOSET
MAID'S RM.
150 CMU 0.80 M HIGH
DOWN
OPEN BELOW
HALLWAY
WALK-IN CLOSET
MASTER'S BEDROOM
REFERENCE DRAWINGS
DWG. NO.
DWG. TITLE
CONTRACTOR COORDINATION/REVIEW
STRUCT.
MECH.
ELEC.
REV
DESCRIPTION
APPROVED
00
ISSUED FOR CONSTRUCTION
KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
CONSTRUCTION OF 100 UNITS KFUPM FACULTY HOUSING 5-BEDROOM VILLA
SHOP DRAWING
GROUND FLOOR PLAN
SENGGUT
10-7-12
1:100


GROUND FLOOR PLAN (5B)
SCALE
METERS
FAMILY DINING
FAMILY LIVING
KITCHEN
ARCH
ABAYA
LAUNDRY
150mm CMU
(CLEAR DISTANCE)
STO.
ELECT.
WASH
TOILET
DINING ROOM
HALLWAY
STUDY ROOM
FOYER
RECEPTION
PORCH
UP
GRANITE TILE FIN.

APPENDIX D

(Document: List of reported problems made by occupants)

The following table is a list of problems faced by occupants of Al-Marooj Courts at KFUPM, this document was prepared by some of the occupants and presented to the researcher during the course of conducting the questionnaire surveys. It has been used as a secondary source of data.

List of Problems Reported in the New Marooj Houses
Technical Issues
Improper design of gas-outlet in the kitchen which is a potential safety-hazards
The most annoying problem in my house and I think in many others (in addition to all problems mentioned earlier) is the AC air flow noise it is too high and I think it can be much reduced by presetting of the air flow and the AC air supply diffuser grills..
The AC unit. It does not seem to start/stop automatically as it is supposed to be.
Lighting in the first floor of the houses is excellent. However, it is relatively poor upstairs in the bedrooms.
A screen door to the kitchen door, for better ventilation is needed
Improper design of gas-outlet in the kitchen which is a potential safety-hazards
The excessive extension of the gas-outlet in the kitchen needs to be explicitly added as a (health/safety/danger) risk issue to be swiftly resolved by the Department of EHS;
No **smoke detector** and no fire **alarm**
e major problems I faced were when I needed help from the university maintenance or housing. For mple, my dryer was burnt out because of a defect in the electricity of its outlet and when I talked to UPM appliances they "unsurprisingly" said it's neither their fault nor the contractor's. But they ankfully" facilitated my purchase of a new one at a "fairly-reduced" price.
Functional Isssues
Improper design of excessively elevated bath-tub (... and this can be a continuous future nuisance to the family ... and may even be unsafe for one to get in and get out of the bath-tub)?! ... and that have caused the contractor to even avoid installing the sliding-glass door initially designed and seemingly must (have been procured and paid for...) to meet part of the project-design specifications. .
The bathtub in the master bedroom is a kind of high and needs a long step to get in and out from it – it is specially difficult and risky for women during pregnancy period for instance.
Water leakage was observed from the ceiling in the family dining room. In another house, water leakage from the ceiling happened after using the shower in the bathroom of the maiden room upstairs. I think there is no damp proofing at all (or of very bad quality).
There should be accessible valve for each bathroom (what if there is any water leakage, you need to close the master valve which is underground outside the house ... at least one valve in each floor and one at the house entrance).

	No shower in any bathroom downstairs. It is suggested that the washings station in the bathrooms downstairs be replaced with showers – already there are washing stations outside the bathrooms.
	The new houses have only one faucet in the kitchen that has sweet water. All the other faucets have salty water. The salinity of the water is too high for washing the mouth and is not healthy for hair and skin and will quickly bleach our clothes. Salty water is also very corroding. As you can see on the picture, my new kitchen has leaking pipes and the water has already started corroding the wall and the wood. I do not understand why all other housing areas have sweet water (as far as I know) and the new houses do not?!
	The serious issues of plumbing will cause problems in the future and may affect the walls, ceiling, wood and even the structure of the house. Some problems do not show in the first few days of occupancy but may become apparent in few weeks or few months. This will cost the university a lot resources for repair and maintenance, and will cause a lot of inconvenience and headache for the tenants.
	I have lost one radio set and one shaving machine which were both burnt because what seemed to be 110-V outlet was actually 220-V outlet!
	The kitchen and bathroom tiles are very bad and some are poorly fixed.
	The quality of painting is not high and even with little water it can be corrupted.
	The bidet in the bathroom of the master bedroom is too close the cabinet of the sink.
	Another water faucet in the backyard is needed.
	The size of the bathroom in the master bedroom is small
	The master bedroom is probably larger than what is needed. However, the dressing area and the bathroom are smaller than what is probably needed. The closets are relatively small.
	The size of the bathrooms downstairs is too small.
	The toilet – paper dispenser in the bathroom of the master bedroom is relatively far to reach by the toilet- user. In the other two toilets upstairs, it is behind the toilet user!!
	Behavioural Issues
	Not satisfied with the paint, tiles, water leakage, stains all over the house, unsealed bath tubs - the finishing is very low quality. I think the finishing quality is much lower than the University standards and we the faculty deserves much better than that.
	The finishing is very low quality
	There is lack of family-privacy-considerations when one closely study the possible-visual skyline-extrapolation to each housing-unit from the neighbouring house-unit across the street.

APPENDIX E

(Preliminary Interview with building occupants)

The following tables are the result of a preliminary interview made with three occupants of Al-Marooj Courts at KFUPM to discover areas of major concern to them, and subsequently ensure these areas are adequately taken into consideration in developing the questionnaire tool.

Important areas for consideration derived through an interview	
	Technical Issues
	Too much lighting
	Noise from the HVAC system
	Functional Isssues
	Difficulty in controlling indoor environment due to poor operation of thermostat
	Dust coming from air infiltration – doors are not properly sealed
	Master-bedroom is disproportionate with its wash-room facility i.e. washroom too small compared to large size of bedroom
	Too much concrete in the estate – insufficient greenery and landscaping
	In the case of a downpour of rain, ponding occurs in the compound – not well drained to the outside
Interviewee 01	Electrical outlets not standard – quasi American outlets were used
	Size of room for the house-help is not standard – too small
	Water pipes in the yard are very shallow, so in summer you get hot water
	Water lines are buried in HVAC channel and sealed, no consideration for maintenance when there is a leak which has occurred
	TV and telephone lines packed together, and cannot be differentiated
	The bell can be answered automatically, but the door has to be opened manually
	Concrete flooring in compound is very rough for kids
	Lack of playground for kids
	No facility for ladies for exercise and other feminine activities in the estate
	Behavioural Issues
	Too private and affects the accessibility of service men
	Finishing is bad – especially tile work in the bathroom
	Quality of material is very poor - leakage from pipe did not occur at joints rather from the body of the material

Important areas for consideration derived through an interview	
Interviewee 02	**Technical Issues**
	Too much indoor and outdoor lighting
	Noise from HVAC
	Bad ventilation
	Air movement is slow
	Functional Issues
	Bad location of thermostat
	Extractor fans in kitchen is bad
	Behavioural Issues
	Insufficient greenery – trees are being cut
	Poor Quality of floor finishes
	General architectural design is bad

Important areas for consideration derived through an interview	
Interviewee 03	**Technical Issues**
	HVAC unit air outlet directly towards occupants
	Lightning in the bedrooms is too low – not adequate for reading
	No fire alarm in the building
	Functional Issues
	Operation of the thermostat
	Availability of hot water – operation of water heater
	Occupants are not educated on how to use IT connections
	Washrooms in the lower floor have no shower facility
	Master bedroom is larger than needed - with washroom facility and bath-tub too small
	Driver's room is useless
	Dryer gets blocked frequently
	Electrical outlets are American standard and require adaptors and extensions
	Behavioural Issues
	Insufficient greenery – trees are being cut
	Green lawn in the yard requires too much maintenance
	Occupants are not allowed to plant trees
	Poor construction of floor tiles
	No privacy for ladies in the yard due to proximity

APPENDIX F

(Expert Questionnaire Survey: Indoor Environment)

King Fahd University of Petroleum and Minerals

College of Environmental Design

Architectural Engineering Department

SUBJECT: Questionnaire Survey for Thesis Research

As–Salaam 'Alaikum Wa–Rahmatullaah Wa–Barakaatuh

Mr. MUIZZ OLADAPO SANNI ANIBIRE is a graduate student in the Architectural Engineering Department at King Fahd University of Petroleum and Minerals. He is currently in the data collection stage for his Masters thesis titled "**A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF Al–MAROOJ COURTS AT KFUPM**". To this end, he needs you to respond to few questions through a questionnaire survey. I hope you will extend any help you can to make his research successful. The data will be used solely for research purposes and respondents identities will not be shared with third parties.

Your co-operation in this research will be highly appreciated.

Dr. Mohammad A. Hassanain
Associate Professor,
Architectural Eng. Dept.
KFUPM, Dhahran 31261, KSA
Tel: +966-5-59744968
Email: mohhas@kfupm.edu.sa

Background

This questionnaire survey is being conducted to review a list of performance indicators relevant to residential housing. Your professional experience will go a long way in helping to decide what indicators should or should not be included and how best should they be asked. This research also requires that the indicators should be rated in relative importance, so that the most important indicator receives the highest rating.

The results of this research will help to determine areas that need improvement and also aid in future planning and design of university residential houses and ultimately improve the well-being of its occupants. Thus your diligent support and patience is crucial to the success of this study.

Please fill in the respondent's background information in part 1 as required and then proceed to the questionnaire in part 2:

Part 1: **Respondent's Background Information**

1. Respondents Profile (Optional)

Name: ……………………………………………………………………………………

Company Name: ………………………………………………………………………...

Telephone no: ……………………………………………………………………………

Email Address: …………………………………………………………………………..

Company Address: ………………………………………………………………………

2. **What is your position in the organisation? (Please tick)**

Architectural Engineer	☐
Indoor Environmental Specialist	☐
HVAC Engineer	☐
Facility Manager	☐
Architect	☐
Others, please specify	☐

3. **How long is your professional experience related to residential buildings? (Please tick)**

a) Less than 5 years	☐	b) 5 to 10 years	☐
c) 10 to 20 years	☐	d) Over 20 years	☐

4. **What is the nature of the residential buildings in which you have professional experience? (Please tick)**

Single-family buildings	☐
Multi-family buildings	☐

5. **What is the size of the largest project you have worked on? (Please tick)**

a) Less than 50 family units	☐	b) 50 to 100 family units	☐
c) 100 to 500 family units	☐	d) Over 500 family units	☐

Part 2: **Questionnaire Survey**

Instructions: for each of the questions please tick with the sign **(√)** to indicate your perception of the relative importance of the criteria mentioned.

Extra spaces are also provided so you can additional criteria not already mentioned and their respective level of performance.

We greatly appreciate your co-operation for the successful completion of this study.

Key:

	Importance ratings
1	Slightly Important
2	Minor Importance
3	Important
4	Very Important
5	Extremely Important

Technical Performance Elements					
Thermal Comfort	Level of Importance				
	1	**2**	**3**	**4**	**5**
Indoor Temperature in winter					
Indoor Temperature in summer					
Indoor Temperature shifts (stability)					
Indoor Humidity					
Air movement					
Incoming sun					
Drafts from windows/vents					
Location/Accessibility of thermostat					
Control of thermostat					
Overall satisfaction with thermal comfort					
Please add other indicators that you think are necessary					

Technical Performance Elements					
Indoor Air Quality	Level of Importance				
	1	2	3	4	5
Indoor Temperature					
Indoor Humidity					
Adequacy of natural ventilation					
Adequacy of mechanical ventilation					
Air freshness in summer					
Air freshness in winter					
Odour/Air pollution					
Air Flow					
Overall satisfaction with indoor air quality					
Please add other indicators that you think are necessary					

Technical Performance Elements					
Acoustic Comfort	Level of Importance				
	1	2	3	4	5
Noise from neighbours					
Noise from people between rooms					
Noise from vehicles outside					
Noise from air/HVAC system					
Noise from lighting fixtures					
Other noise from outside the building					
Control over noise					
Overall satisfaction with noise					
Please add other indicators that you think are necessary					

Technical Performance Elements					
Visual Comfort	Level of Importance				
	1	2	3	4	5
Amount of daylight (natural lighting)					
Illumination level/How bright are the lights (artificial lighting) in the living room					
Illumination level/How bright are the lights (artificial lighting) in the bedrooms					
Control/Use of Electric lighting					
Control of day lighting					
Glare from lights					
Exterior lighting levels in the night					
Adequacy of lighting levels in the corridors of the building					
View to outside					
Overall visual quality in the house during the day					
Overall visual quality in the house in the night					
Please add other indicators that you think are necessary					

APPENDIX G

(Expert Questionnaire Survey: Safety and Security)

King Fahd University of Petroleum and Minerals

College of Environmental Design

Architectural Engineering Department

SUBJECT: Questionnaire Survey for Thesis Research

As–Salaam 'Alaikum Wa–Rahmatullaah Wa–Barakaatuh

Mr. MUIZZ OLADAPO SANNI ANIBIRE is a graduate student in the Architectural Engineering Department at King Fahd University of Petroleum and Minerals. He is currently in the data collection stage for his Masters thesis titled "**A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF Al–MAROOJ COURTS AT KFUPM**". To this end, he needs you to respond to few questions through a questionnaire survey. I hope you will extend any help you can to make his research successful. The data will be used solely for research purposes and respondents identities will not be shared with third parties.

Your co-operation in this research will be highly appreciated.

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Email: mohhas@kfupm.edu.sa

Background

This questionnaire survey is being conducted to review a list of performance indicators relevant to residential housing. Your professional experience will go a long way in helping to decide what indicators should or should not be included and how best should they be asked. This research also requires that the indicators should be rated in relative importance, so that the most important indicator receives the highest rating.

The results of this research will help to determine areas that need improvement and also aid in future planning and design of university residential houses and ultimately improve the well-being of its occupants. Thus your diligent support and patience is crucial to the success of this study.

Please fill in the respondent's background information in part 1 as required and then proceed to the questionnaire in part 2:

Part 1: **Respondent's Background Information**

1. **Respondents Profile (Optional)**

Name: ……………………………………………………………………………………

Company Name: ………………………………………………………………………….

Telephone no: ……………………………………………………………………………

Email Address: ………………………………………………………………………….

Company Address: ………………………………………………………………………

2. **What is your position in the organisation? (Please tick)**

Architectural Engineer	☐
Facility Manager	☐
Maintenance Engineer/Manager	☐
Security and Safety Personnel	☐
Architect	☐
Others, please specify	☐

3. **How long is your professional experience related to residential buildings? (Please tick)**

a) Less than 5 years	☐	b) 5 to 10 years	☐
c) 10 to 20 years	☐	d) Over 20 years	☐

4. **What is the nature of the residential buildings in which you have professional experience? (Please tick)**

Single-family buildings	☐
Multi-family buildings	☐

5. **What is the size of the largest project you have worked on? (Please tick)**

a) Less than 50 family units	☐	b) 50 to 100 family units	☐
c) 100 to 500 family units	☐	d) Over 500 family units	☐

Part 2: **Questionnaire Survey**

Instructions: for each of the questions please tick with the sign **(√)** to indicate your perception of the relative importance of the criteria mentioned.

Extra spaces are also provided so you can additional criteria not already mentioned and their respective level of performance.

We greatly appreciate your co-operation for the successful completion of this study.

Key:

	Importance ratings
1	Slightly Important
2	Minor Importance
3	Important
4	Very Important
5	Extremely Important

Technical Performance Elements					
Safety and Security	Level of Importance				
	1	2	3	4	5
Security system of your house					
Quality and perception of fire safety systems in the building					
Ease to identify Emergency/Escape route					
Ease of exiting the building in cases of fire emergencies					
Ease to identify and reach fire alarm systems					
Anti-crime measures					
Level of security in the neighbourhood					
Level of safety measures in children playground areas					

Level of safety measures in streets and walkways					
Availability of emergency preparedness measures in outdoor planning					
Enforcement of maximum speed limit rules					
Quality of provided speed pumps					
Quality of landscape design in facilitating safe driving					
Protection against insects and dangerous animals					
Overall satisfaction with safety and security					
Please add other indicators that you think are necessary					

APPENDIX H

(Expert Questionnaire Survey: Building Maintenance)

King Fahd University of Petroleum and Minerals

College of Environmental Design

Architectural Engineering Department

SUBJECT: Questionnaire Survey for Thesis Research

As–Salaam 'Alaikum Wa–Rahmatullaah Wa–Barakaatuh

Mr. MUIZZ OLADAPO SANNI ANIBIRE is a graduate student in the Architectural Engineering Department at King Fahd University of Petroleum and Minerals. He is currently in the data collection stage for his Masters thesis titled "**A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF Al–MAROOJ COURTS AT KFUPM**". To this end, he needs you to respond to few questions through a questionnaire survey. I hope you will extend any help you can to make his research successful. The data will be used solely for research purposes and respondents identities will not be shared with third parties.

Your co-operation in this research will be highly appreciated.

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Please fill in the respondent's background information in part 1 as required and then proceed to the questionnaire in part 2:

Part 1: **Respondent's Background Information**

1. **Respondents Profile (Optional)**

Name: ……………………………………………………………………………………

Company Name: ………………………………………………………………………

Telephone no: …………………………………………………………………………..

Email Address: …………………………………………………………………………

Company Address: ……………………………………………………………………..

2. What is your position in the organisation? (Please tick)

Architectural Engineer	☐
Facility Manager	☐
Maintenance Engineer/Manager	☐
Security and Safety Personnel	☐
Architect	☐
Others, please specify	☐

3. How long is your professional experience related to residential buildings? (Please tick)

a) Less than 5 years	☐	b) 5 to 10 years	☐
c) 10 to 20 years	☐	d) Over 20 years	☐

4. What is the nature of the residential buildings in which you have professional experience? (Please tick)

Single-family buildings	☐
Multi-family buildings	☐

5. What is the size of the largest project you have worked on? (Please tick)

a) Less than 50 family units	☐	b) 50 to 100 family units	☐
c) 100 to 500 family units	☐	d) Over 500 family units	☐

Part 2: **Questionnaire Survey**

Instructions: for each of the questions please tick with the sign **(√)** to indicate your perception of the relative importance of the criteria mentioned.

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Key:

	Importance ratings
1	Slightly Important
2	Minor Importance
3	Important
4	Very Important
5	Extremely Important

Technical Performance Elements					
Management and Maintenance	Level of Importance				
	1	2	3	4	5
Satisfaction with maintenance of building components:					
Exterior paintwork					
Hinges and locks of windows and external doors					
Kitchens					
Drains					
Toilets					
Bathrooms					
Shared areas					
Balconies					
Entrance hall					
Gallery					
Corridor and/or stairs					

Maintenance of installations:					
Heating and water systems					
Ventilation systems					
Lighting in shared areas					
Lifts					
Maintenance of surrounding grounds:					
Paving around the building					
Communal greenery					
Management issues:					
Treatment of residents					
Handling of residents' complaints					
Management response to necessary repairs					
Management team's resources to do the job					
Ease to contact maintenance department					
Maintenance team keep residents informed					
Maintenance team provides good value for money					
Frequency of house maintenance					
Speed and efficiency of maintenance services for indoor facilities					
Others:					
Ease (and cost) of maintenance of house					
Low-cost maintenance features in your house					
Level of Deterioration in building					
Overall satisfaction with management and maintenance of facilities in the housing estate					
Please add other indicators that you think are necessary					

APPENDIX I

(Expert Questionnaire Survey: Health)

King Fahd University of Petroleum and Minerals

College of Environmental Design

Architectural Engineering Department

SUBJECT: Questionnaire Survey for Thesis Research

As–Salaam 'Alaikum Wa–Rahmatullaah Wa–Barakaatuh

Mr. MUIZZ OLADAPO SANNI ANIBIRE is a graduate student in the Architectural Engineering Department at King Fahd University of Petroleum and Minerals. He is currently in the data collection stage for his Masters thesis titled "**A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF Al–MAROOJ COURTS AT KFUPM**". To this end, he needs you to respond to few questions through a questionnaire survey. I hope you will extend any help you can to make his research successful. The data will be used solely for research purposes and respondents identities will not be shared with third parties.

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Please fill in the respondent's background information in part 1 as required and then proceed to the questionnaire in part 2:

Part 1: **Respondent's Background Information**

1. Respondents Profile (Optional)

Name: …………………………………………………………………………………

Company Name: …………………………………………………………………………

Telephone no: ……………………………………………………………………………..

Email Address: ……………………………………………………………………………

Company Address: ……………………………………………………………………….

2. **What is your position in the organisation? (Please tick)**

Indoor Environmental Specialist	☐
Facility Manager	☐
Medical Personnel	☐
Others, please specify	☐

3. **How long is your professional experience related to residential buildings? (Please tick)**

a) Less than 5 years	☐	b) 5 to 10 years	☐
c) 10 to 20 years	☐	d) Over 20 years	☐

4. **What is the nature of the residential buildings in which you have professional experience? (Please tick)**

Single-family buildings	☐
Multi-family buildings	☐

5. **What is the size of the largest project you have worked on? (Please tick)**

a) Less than 50 family units	☐	b) 50 to 100 family units	☐
c) 100 to 500 family units	☐	d) Over 500 family units	☐

Part 2: **Questionnaire Survey**

Instructions: for each of the questions please tick with the sign **(√)** to indicate your perception of the relative importance of the criteria mentioned.

Extra spaces are also provided so you can additional criteria not already mentioned and their respective level of performance.

We greatly appreciate your co-operation for the successful completion of this study.

Key:

	Importance ratings
1	Slightly Important
2	Minor Importance
3	Important
4	Very Important
5	Extremely Important

Technical Performance Elements					
Health	Level of Importance				
	1	2	3	4	5
Do you experience the following regularly:					
Skin reaction (irritation, itchiness, dryness, reddening, rashes)					
Eyes (irritation, itchiness, dryness, watering)					
Nose (irritation, itchiness, congestion, sneezing, nasal, excretion)					
Throat (irritation, dryness, coughing)					
Chest (breathing difficulties, wheezing, tightness of chest)					
Headaches					
Lethargy					
Tiredness					
Overall perception of apartment's effect on					

health					
Please add other indicators that you think are necessary					

APPENDIX J

(Expert Questionnaire Survey: Planning and Architecture)

King Fahd University of Petroleum and Minerals

College of Environmental Design

Architectural Engineering Department

SUBJECT: Questionnaire Survey for Thesis Research

As–Salaam 'Alaikum Wa–Rahmatullaah Wa–Barakaatuh

Mr. MUIZZ OLADAPO SANNI ANIBIRE is a graduate student in the Architectural Engineering Department at King Fahd University of Petroleum and Minerals. He is currently in the data collection stage for his Masters thesis titled "**A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF Al–MAROOJ COURTS AT KFUPM**". To this end, he needs you to respond to few questions through a questionnaire survey. I hope you will extend any help you can to make his research successful. The data will be used solely for research purposes and respondents identities will not be shared with third parties.

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Background

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The results of this research will help to determine areas that need improvement and also aid in future planning and design of university residential houses and ultimately improve the well-being of its occupants. Thus your diligent support and patience is crucial to the success of this study.

Please fill in the respondent's background information in part 1 as required and then proceed to the questionnaire in part 2:

Part 1: **Respondent's Background Information**

1. Respondents Profile (Optional)

Name: ………………………………………………………………………………………

Company Name: ……………………………………………………………………

Telephone no: ………………………………………………………………………..

Email Address: ……………………………………………………………………….

Company Address: …………………………………………………………………..

2. **What is your position in the organisation? (Please tick)**

Architectural Engineer	☐
Facility Manager	☐
Architect	☐
Others, please specify	☐

3. **How long is your professional experience related to residential buildings? (Please tick)**

a) Less than 5 years	☐	b) 5 to 10 years	☐
c) 10 to 20 years	☐	d) Over 20 years	☐

4. **What is the nature of the residential buildings in which you have professional experience? (Please tick)**

Single-family buildings	☐
Multi-family buildings	☐

5. **What is the size of the largest project you have worked on? (Please tick)**

a) Less than 50 family units	☐	b) 50 to 100 family units	☐
c) 100 to 500 family units	☐	d) Over 500 family units	☐

Part 2: **Questionnaire Survey**

Instructions: for each of the questions please tick with the sign **(√)** to indicate your perception of the relative importance of the criteria mentioned.

Extra spaces are also provided so you can additional criteria not already mentioned and their respective level of performance.

We greatly appreciate your co-operation for the successful completion of this study.

Key:

	Importance ratings
1	Slightly Important
2	Minor Importance
3	Important
4	Very Important
5	Extremely Important

Functional Performance Elements					
Layout, Furniture and Spatial Comfort	Level of Importance				
	1	2	3	4	5
Type of House					
Plot size					
Adequacy of circulation routes around the building					
Space for landscaping					
No of rooms in your house					
Location of rooms in your house					
Suitability of the location of bathrooms relative to guest reception area					
Room performance/Layout of the rooms					
Functionality in design					
Vertical circulation within building					

Horizontal circulation within building					
Scale and proportion of the floor plan					
Ceiling height (head room)					
Size of individual spaces:					
Master Bedroom					
Maid's Bedroom					
Bedroom 1					
Bedroom 2					
Bedroom 3 (if applicable)					
Reception					
Study room					
Dining room					
Family Living room					
Personal storage/Capacity of Wardrobe					
Overall satisfaction with amount of Space/Size of the rooms					
Quality of carpentry work for:					
Doors and windows					
Kitchen					
Bathroom cabinets					
Closets (wardrobe)					
Reception					
Study room					
Family dining room					
Family living room					
Master Bedroom					
Maid's Bedroom					
Bedroom 1					
Bedroom 2					
Bedroom 3 (if applicable)					
Please add other indicators that you think are necessary					

Functional Performance Elements					
Housing Support Services	Level of Importance				
	1	2	3	4	5
Stability of power					
Availability and quality of drinking water					
Adequacy of power sockets					
Flexibility of IT/TV connection points					
The type of electrical outlets used					
The number and position of electrical sockets					
The operation of electrical fittings					
Operation of Windows					
Windows for kitchen or bathroom					
Effectiveness of windows in preventing dust					
Operation of Doors					
Operation of Door bell and opening system					
Effectiveness of doors in preventing dust					
The functioning of plumbing fittings					
Number of washroom facilities (T/B)/Adequacy of washroom facilities					
Size of T/B in Master Bedroom					

Size of T/B in Maid's Bedroom					
Size of T/B in Bedroom 1					
Size of T/B in Bedroom 2					
Size of T/B in Bedroom 3 (if applicable)					
Storm-water drainage system					
Refuse disposal system/ Cleanliness and trash removal					
Efficiency of insect spray services					
Accessibility to disabled and aged people					
Street lightning					
Open spaces, parks and reserves					
Availability and children's play-ground and ladies centre					
Availability of good roads and sidewalks					
Design of on-site car parking space is efficient (roof, space arrangement)					
Adequacy of off-street parking					
Adequacy of artificial lighting levels in the car parking space					
Capacity and Efficiency of utility systems:					
Sewage systems					
Electrical					
Water supply					
Gas					
Refrigerator					
Stove					
Oven					
Kitchen exhaust vent					
Washing machine					
Dryer					
Internet/Television connection points					
Lifts					
Please add other indicators that you think are necessary					

Behavioural Performance Elements					
Privacy and Territoriality	Level of Importance				
	1	2	3	4	5
The level of privacy within spaces in your house					
Privacy from your neighbours					
Distance of your building from your side boundary fence					
Distance of your building from the rear boundary fence					
Building setback					
Density of Population within the estate					
Overall satisfaction with privacy and territoriality					
Please add other indicators that you think are necessary					

Behavioural Performance Elements					
Location	Level of Importance				
	1	2	3	4	5
Size of estate					
Appropriateness of location for residential buildings					

Location of House in estate					
Proximity/Nearness of your house to:					
Places of worship					
Children's schools					
Friends					
Market and shopping centres					
Recreational/Sport facilities					
Workplace					
Medical facilities					
Fire fighting station					
Transportation amenities					
Police station					
Restaurants					
Library					
Others					
Extent of social relation among neighbours					
Prices of goods and services in the housing estate					
Job/Business opportunities within and around the housing estate					
Level of crime and anti-social activities in the housing estate where you live					
Suitability to natural way of life					
Rule and regulations of housing estate					
Please add other indicators that you think are necessary					

Behavioural Performance Elements					
Appearance	Level of Importance				
	1	2	3	4	5
Design and quality of:					
Toilets					
Kitchen					
Bathrooms					
Quality of materials used in:					
Floors					
Ceilings					
Walls					
Paints					
Others:					
Colours used in exterior of the house					
Colours used in interior of the house					
Quality and Presentation of finishes in common spaces					
Streets and foot paths design					
Green areas (vegetation)					
Landscaping of neighbourhood					
General aesthetic appearance					
Please add other indicators that you think are necessary					

APPENDIX K

(Occupant's Questionnaire Survey)

King Fahd University of Petroleum and Minerals

College of Environmental Design

Architectural Engineering Department

SUBJECT: Questionnaire Survey for Thesis Research

As–Salaam 'Alaikum Wa–Rahmatullaah Wa–Barakaatuh

Mr. MUIZZ OLADAPO SANNI ANIBIRE is a graduate student in the Architectural Engineering Department at King Fahd University of Petroleum and Minerals. He is currently in the data collection stage for his Master's thesis titled "**A HOLISTIC FRAMEWORK FOR THE POST OCCUPANCY EVALUATION OF CAMPUS RESIDENTIAL HOUSING FACILITIES – CASE STUDY OF Al–MAROOJ COURTS AT KFUPM**". To this end, he needs you to respond to few questions through a questionnaire survey. I hope you will extend any help you can to make his research successful. The data will be used solely for research purposes and respondents identities will not be shared with third parties.

Your co-operation in this research will be highly appreciated.

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Background

This questionnaire survey is being conducted to gain insight as regards the quality and performance of your residential housing. This will help to determine areas that need improvement and also aid in future planning and design of university campus residential houses and ultimately the well being of its occupants. Thus your diligent support and patience is crucial to the success of this study.

The information collected will be kept strictly confidential by the research team, and identities of individuals will not be revealed. The questionnaire should either be filled by the head of the household or any other adult member of the household who has spent over 6 months in the house.

Please fill in the respondent's background information in part 1 as required and then proceed to the questionnaire in part 2, additional spaces are provided for any extra comments you may have. Your diligent support and patience is crucial to the success of this study.

In case you have any queries please contact:

Mr. Muizz Anibire (Researcher)

Tel: +966-5-01296203

E-mail: g201202280@kfupm.edu.sa

Part 1: Respondent's Background Information

a. Respondents Profile

Name (Optional): ....

Sex: Male ☐ Female ☐

Age: ....

Nationality: ....

b. How long have you lived in the house? (Please tick)

a. More than 6 months	☐	b. More than a year	☐

c. What is the nature of occupants in your house?

Number of Adults	
Number of Children	

d. What is the average number of hours you spend in your house? (Please tick)

a. More than 7 hours	☐	b. More than 12 hours	☐

Part 2: **Questionnaire Survey**

Instructions: for each of the questions please tick with the sign **(**√**)** to indicate your level of satisfaction. Extra spaces are provided for you to add any further comments. We greatly appreciate your co-operation for the successful completion of this study.

Key:

	Level of Satisfaction
1	Very Dissatisfied
2	Dissatisfied
3	Neutral
4	Satisfied
5	Very Satisfied

Thermal Comfort	Level of Satisfaction				
	1	**2**	**3**	**4**	**5**
Indoor temperature in winter					
Indoor temperature in summer					
Indoor temperature shifts (stability)					
Indoor humidity					
Air movement					
Incoming sun					
Drafts from windows/vents					
Location/Accessibility of thermostat					
Control of thermostat					
Overall satisfaction with thermal comfort					
Further Comments					
Indoor Air Quality	Level of Satisfaction				
	1	2	3	4	5
Adequacy of natural ventilation					

Adequacy of mechanical ventilation					
Air freshness in summer					
Air freshness in winter					
Odour/Air pollution					
Air flow					
Overall satisfaction with indoor air quality					
Further Comments					

Acoustic Comfort	Level of Satisfaction				
	1	2	3	4	5
Noise from neighbours					
Noise from people between rooms					
Noise from vehicles outside					
Noise from air/HVAC system					
Noise from lighting fixtures					
Other noise from outside the building					
Control over noise					
Overall satisfaction with noise					
Further Comments					

Visual Comfort	Level of Satisfaction				
	1	2	3	4	5
Amount of daylight (natural lighting)					
Illumination level/How bright are the lights (artificial lighting) in the living room					
Illumination level/How bright are the lights (artificial lighting) in the bedrooms					
Control/Use of electric lighting					
Control of day lighting					
Glare from lights					
Exterior lighting levels in the night					
Adequacy of lighting levels in the corridors of					

the building					
View to outside					
Overall visual quality in the house during the day					
Overall visual quality in the house in the night					
Further Comments					

Safety and Security	Level of Satisfaction				
	1	2	3	4	5
Security system of your house					
Quality and perception of fire safety systems in the building					
Ease to identify emergency/escape route					
Ease of exiting the building in cases of fire emergencies					
Anti-crime measures					
Level of security in the neighbourhood					
Level of safety measures in children playground areas					
Level of safety measures in streets and walkways					
Availability of emergency preparedness measures in outdoor planning					
Enforcement of maximum speed limit rules					
Quality of provided speed bumps					
Quality of landscape design in facilitating safe driving					
Protection against insects and dangerous animals					
Overall satisfaction with safety and security					
Further Comments					

Management and Maintenance	Level of Satisfaction				
	1	2	3	4	5
Satisfaction with maintenance of building components:					
Exterior paintwork					
Hinges and locks of windows and external doors					
Kitchens					
Drains					
Toilets					
Bathrooms					
Maintenance of installations:					
Heating and water systems					
Ventilation systems					
Lighting in shared areas					
Maintenance of surrounding grounds:					
Paving around the building					
Communal greenery					
Management issues:					
Treatment of residents					
Handling of residents' complaints					
Management response to necessary repairs					
Management team's resources to do the job					
Ease to contact maintenance department					
Maintenance team keep residents informed					
Maintenance team provides good value for money					
Frequency of house maintenance					
Speed and efficiency of maintenance services for indoor facilities					
Others:					
Ease (and cost) of maintenance of house					

Low-cost maintenance features in your house					
Level of Deterioration in building					
Overall satisfaction with management and maintenance of facilities in the housing estate					
Further Comments					

Layout, Furniture and Spatial Comfort	Level of Satisfaction				
	1	2	3	4	5
Type of house					
Plot size					
Adequacy of circulation routes around the building					
Space for landscaping					
No of rooms in your house					
Location of rooms in your house					
Suitability of the location of bathrooms relative to guest reception area					
Room performance/Layout of the rooms					
Functionality in design					
Vertical circulation within building					
Horizontal circulation within building					
Scale and proportion of the floor plan					
Ceiling height (head room)					
Size of individual spaces:					
Master bedroom					
Maid's bedroom					
Bedroom 1					
Bedroom 2					
Bedroom 3 (if applicable)					
Reception					
Study room					
Dining room					
Family living room					

Personal storage/Capacity of wardrobe					
Overall satisfaction with amount of Space/Size of the rooms					
Quality of carpentry work for:					
Doors and windows					
Kitchen					
Bathroom cabinets					
Closets (wardrobe)					
Reception					
Study room					
Family dining room					
Family living room					
Master bedroom					
Maid's bedroom					
Bedroom 1					
Bedroom 2					
Bedroom 3 (if applicable)					
Further Comments					

Housing Support Services	Level of Satisfaction				
	1	2	3	4	5
Stability of power					
Availability and quality of drinking water					
Adequacy of power sockets					
Flexibility of IT/TV connection points					
The type of electrical outlets used					
The number and position of electrical sockets					
The operation of electrical fittings					
Operation of windows					
Windows for kitchen or bathroom					

Effectiveness of windows in preventing dust					
Operation of doors					
Operation of door bell and opening system					
Effectiveness of doors in preventing dust					
The functioning of plumbing fittings					
Number of washroom facilities (T/B)/Adequacy of washroom facilities					
Size of T/B in master bedroom					
Size of T/B in maid's bedroom					
Size of T/B in bedroom 1					
Size of T/B in bedroom 2					
Size of T/B in bedroom 3 (if applicable)					
Storm-water drainage system					
Refuse disposal system/Cleanliness and trash removal					
Efficiency of insect spray services					
Accessibility to disabled and aged people					
Street lightning					
Open spaces, parks and reserves					
Availability and children's play-ground and ladies centre					
Availability of good roads and sidewalks					
Design of on-site car parking space is efficient (roof, space arrangement)					
Adequacy of off-street parking					
Adequacy of artificial lighting levels in the car parking space					
Capacity and Efficiency of utility systems:					
Sewage systems					
Electrical					
Water supply					
Gas					
Refrigerator					
Stove					

Oven					
Kitchen exhaust vent					
Washing machine					
Dryer					
Internet/Television connection points					
Further Comments					

Privacy and Territoriality	Level of Satisfaction				
	1	2	3	4	5
The level of privacy within spaces in your house					
Privacy from your neighbours					
Distance of your building from your side boundary fence					
Distance of your building from the rear boundary fence					
Building setback					
Density of population within the estate					
Overall satisfaction with privacy and territoriality					
Further Comments					

Location	Level of Satisfaction				
	1	2	3	4	5
Size of estate					
Appropriateness of location for residential buildings					
Location of house in estate					
Proximity/Nearness of your house to:					

Places of worship					
Children's schools					
Friends					
Market and shopping centres					
Recreational/Sport facilities					
Workplace					
Medical facilities					
Fire fighting station					
Transportation amenities					
Police station					
Restaurants					
Library					
Others					
Extent of social relation among neighbours					
Prices of goods and services in the housing estate					
Job/Business opportunities within and around the housing estate					
Level of crime and anti-social activities in the housing estate where you live					
Suitability to natural way of life					
Rule and regulations of housing estate					
Further Comments					

Appearance	Level of Satisfaction				
	1	2	3	4	5
Design and quality of:					
Toilets					
Kitchen					

Bathrooms					
Quality of materials used in:					
Floors					
Ceilings					
Walls					
Paints					
Others:					
Colours used in exterior of the house					
Colours used in interior of the house					
Quality and Presentation of finishes in common spaces					
Streets and foot paths design					
Green areas (vegetation)					
Landscaping of neighbourhood					
General aesthetic appearance					
Further Comments					

APPENDIX L

(Open-Ended questionnaire feed-back)

The feed-back collected from the open-ended section of the questionnaire survey is presented in their respective categories below.

Thermal Comfort
Temperature is not uniform in the house, air is stronger in certain places VS others
Strong air flow
There is no fan speed control
The flow of the AC is not well balanced, the temperature is high in one area and low in another
A major problem with air conditioning is that the AC thermostat does not work. The maintenance from Al-Zamil came many times with no success in fixing the problem. Therefore, we just turn AC on when temperature goes up and turn it of when it gets too cod, and for this reason the compressor of then AC has been replaced not than 5 times.
The openings for air flow from the AC are not placed properly. They are in the ceiling right on top of where we sit in living rooms, dining rooms and the kitchen.
The upper level AC never shuts down automatically because the thermostat is placed in a location that never reflects the room bedroom temperatures. We have to turn it and off manually.
The air draft in the bedrooms is very noisy and does not allow us to sleep if the AC is on.
Location of the thermostat and the air movement around it is a real problem. In summer, we have to make the switch from on to off then off to on manually such that someone has to wake up in the middle of the night to turn it on since it becomes too hot, then after a couple of hours has to switch it off again when it is colder and so on. This is a continuous and it seems, never ending problem that no one is able to solve.
Lots of waste resources in having only two thermostat.
The thermostat does not work at all in the ground floor and we have to switch on and of f manually. Tries tens of times with maintenance to solve the problem but still the same. The AC unit in the first floor made several major breakdown including compressor, noise and ultra vibration causing belt changes and so on.
No control of thermostat which make us either turn off the AC or stay cold all night.
AC's are not well installed. Dust comes out of them. They need proper filters
There is a problem with the control of the AC. The draft noise is too high
I do not think the thermostat is working properly
There should be more AC controls.
The airflow from AC is terrible; particularly, in the bedrooms

Indoor Air Quality
The vents in kitchen and lower floor rooms bring in dust especially in the kitchen, the vent blowing into the kitchen has turned black from dust
Kitchen vent is so noisy that rarely used

Acoustic Comfort
Voices are heard between rooms easily
AC makes a lot of noise
There seems to be no sound insulators at all – sounds from TV or from people talking anywhere in the house could be heard clearly in other places in the house.
Sounds of ventilation devices in the kitchen and in bathrooms as well are noisy.
Sound of the AC is loud also.
House produces echoes of all sounds including occupants, TV, radio, etc.
AC noise is excessive when windows are open.

Visual Comfort
Lights in the bed room are not adequate enough
Need more lights in smaller bedrooms
Main door light is not enough
Front yard is dark
We had to replace all bulbs from cool white to cool yellow
Amount of lighting in all bedrooms was not enough. We had to install additional lights in all bedrooms. Living rooms, dining rooms, kitchen and bathroom are OK.
Lighting outside the main entrance is not sufficient.
Lighting outside is poor need more light in front and corridors
Light in children bedrooms needs improvement
Lighting in most bedrooms is insufficient except for the master bedroom.

Safety and Security
Need more speed bumps in new streets
There are safety issues, especially near construction areas such as inadequate signs and barriers
Insects in and out the house all the time and they have visited us many times to spray some insecticides but no improvement
There must be surveillance camera at the outside door
There is no fire extinguisher
One key opens all doors is not safe.
The window in the study room (ground floor) can be opened from outside – The maintenance people did not succeed in fixing it. We have the same problem in the master bedroom, however, this is of less safety concern.
There is no fire alarm system.
There are no anticrime measures – we are not aware of any.
Playground is rough concrete
Roads are narrow and there are no spped limit signs in the streets and no speed bumps
We are suffering from insects and ants inside the house (indoors) part of the problem is due to tiles are not well fixed. Pesticides people comes every Thursday, however, this does not seem to be enough
There is no fire alarm system or anti-theft security system.
I live next to the main street in Al-Marooj cours, unfortunately, "kids" speed tooo much!! no control!
There is a serious security issues for houses facing the airbase since those houses are not having enough lights outside the house at night time specialy those at the corners or ends of the street. Youth used to hide and misbehave at those dark ends of the street. Three vandilization instances were reported but no action taken.
Playgrounds do not exist. Greenery does not exist. No speed limit signs. No shaded bus stops for kids in summer or under rain.
I do not see any safety measures in homed or outside only fire extenguatior
We need more playground to our children like those near Ferdaws
Occupant have no access to electricity panel in case of emergency. Only one fire extinguisher in the whole house. No smoke detector. Outdoor ground cover (concrete) is unsafe for children. No shower in ground level. No access for disabled persons.

Maintenance and Management
Quality of Paint on exterior of house (on windows) is very bad. It has already changed into cracked flakes.
The is no greenery in the neighbourhood
After putting requests for several times, nobody comes to look after the maintenance. The persons receiving the requests are highly careless and unaccountable. For example, I have made calls at 7000 for four times, but till date nobody has come to fix the problem in the water heater
Locks of some windows (study room and master bedroom) are not good.
Cabinets in the kitchen are at higher than normal
Bathrooms are very congested small area with a very poor design.
No shower bathrooms in the ground level
Doors and cabinets in bathrooms should be from aluminium not wood to avoid damage due to water
Very difficult to step in the bathtub in the bathroom of master bedroom
Ventilation fans in all bathrooms are weak
No greenery areas at all
Main control for water and gases is placed under the parking lot – it could happen that a car is parking on this area blocking access at time of emergency
Whenever there is rain, water starts leaking in the kitchen. Made complaints, but nothing has been done so far.
Overall satisfactory. However, some issues that seems trivial but maintenance cannot handle properly, for example water heating has a major problem, water takes too long time to be heated and this problem could not be solved although it results in loss of water till it starts to get heated after at least 5 minutes of running water. Water heating is too weak in the lower floor. Nowadays, it is week everywhere and we can hardly get tepid water in spite of frequent requests to Maintenance.
The concrete slabs around the building were broken due to levelling problem (it seems)
The water heater keeps switching off almost weekly, it takes one DAY for the maintenance to come and start it, I wish we can get the keys and we can start it ourselves as it is easy to do!
Hot water keeps cutting. Maintenance people take up to 4 hours
The quality of the hinges and locks not good start to corroded. Drainage system not good also. The building and outside area start to show cracks
The solar system could have been used instead of the gas heating for the hot water heater.
We are still waiting for management to change outdoor grounding and make our houses accessible for disabled persons.

Housing Support services
Bathing facility is not available at ground floor
No shower facility on ground floor (very poor design). It's difficult for old and people with disability to use upstairs shower
One of the toilets in the ground floor must be converted into bathroom
All showers are upstairs which makes it very inconvenient to old people and guests
Drivers are not allowed to reside in small rooms in parking garage
Air draft from the doors is present and bring in lots of dust and sand. They need to be properly sealed against drafts
Need 3-pin large 220V outlets in rooms, especially in kitchen since most electronic appliances come with those plugs
Ramp for car parking is too steep, it hits the underside of vehicle
Master Bedroom toilet size very small/poor design
Electrical outlets are old type specially for the 220 V
No door interphone in the upstairs level
Main door
No playgrounds for children
Kitchen exhaust vent is very noisy
The first floor should have a shower in the guests bathroom
Gas for water heater keeps cutting every other day as mentioned before
Refrigerators are too small compared to what we had before

Layout, furniture and spatial comfort
Maids bedroom too small
The maid's bedroom is too small
Maids bedroom too small
Maids bedroom too small
The best house I have ever been here, but there are somethings that need to be fixed
The carpentry material is poor quality
Location of the kitchen is not suitable
Entrance doors expand during the day due to high temperature making them difficult to be closed sometimes
Bathroom cabinets should be made from aluminum – wood on repeated exposure to humidity gets damaged
Closets should have sliding doors, my daughter 1 year old daughter was injered from the closets

door!! Sliding doors should be safer
Ceiling is too high
Doors have large space between the leaf and frame. Causes excessive infiltration and energy loss. Also admits lots of DUST from outside.

Privacy and Territoriality
There is no privacy for neighbours opposite to each other
We can see the inside of our neighbours house and they can see us - no privacy – this is a serious concern specially for ladies
Front yard is totally exposed to neighbours.

Appearance
The external paint is very rough. Many kids have had bruises with the external walls resulting in serious injuries, replacing it with a smooth paint will be safer. Same issue with the external floor, the present one is very rough and kids are prone to injury during play. It must be changed as well.
Toilet fixtures (nuts and screws, cabinet hinges etc – all metal) started to rust even before we moved in the house. The contractor certainly used inadequate quality of material in bathrooms and toilets.
Green areas/garden should be filled with soil and not sand. Even the plants/ grass should not be planted. It should be filled only with soil and flowering plants. The sand keeps blowing and requires regular clean up.
Tiles and paints are of poor quality – we painted our house and have changed the tiles of kitchen, store and bathrooms
Door locks are not of good quality.
The streets in Al-Morooj courts still have no names
The landscaping needs to be improved

Vitae

Name :**MUIZZ OLADAPO SANNI-ANIBIRE**

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